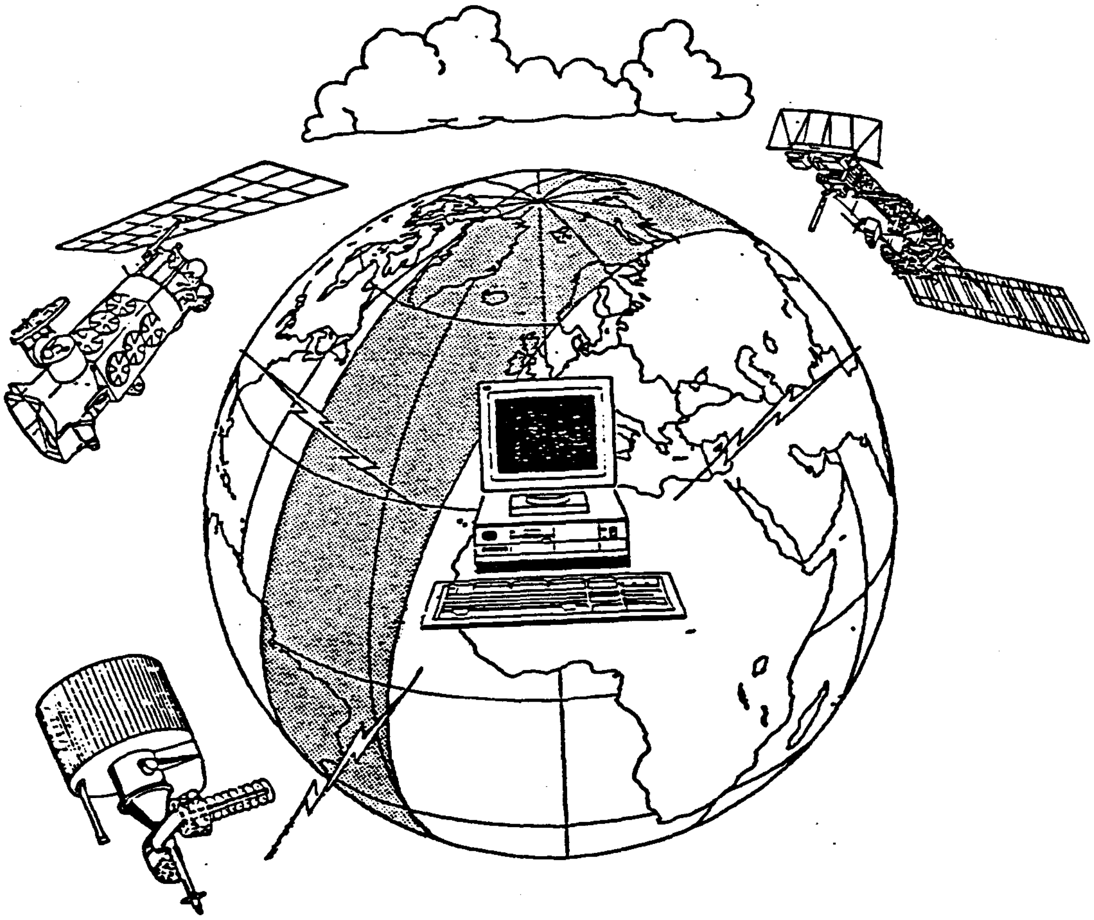
E.5

FUNCTIONAL DESCRIPTION

AFGWC/SYSM



AIR FORCE GLOBAL WEATHER CENTRAL
METEOROLOGICAL MODELS WORKCENTER
(AFGWCISYSM)

FUNCTIONAL DESCRIPTION

AFGWC/SYSM

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Prepared for
Air Force Global Weather Central
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SECTION 1

1.0 General

1.1 Purpose of Functional Description.

This Functional Description for the Air Force Global Weather Central (AFGWC) Meteorological Models Workcenter (SYSM) is written to provide:

a. A description of the models and data that are used by SYSM to provide meteorological analysis and forecasting.

b. An understanding of the impact of the models on DO products.

c. A basis for development of requirements for future upgrades to the AFGWC hardware/software system.

1.2 Project References

The following references apply to this project:

a. DOD-STD-7935A Automated Information Systems Documentation Standards, 31 October 1988

b. AFGWC Pamphlet 105-1, 6 July 1987

c. AFGWC Real-Time Cloud Analysis Model, Technical Note 88/001

d. AFGWC Data Format Handbooks, Vol. 1,2/Version 1, March 90

e. AFGWC Cloud Forecast Models, Technical Note 87/001

f. AFGWC Analysis/Forecast Model System, Technical Note 79/004

g. AFGWC Snow Analysis Model, Technical Note 86/001

h. AGRMET Model Description

i. A Worldwide Near Real-Time Diagnostic Agrometeorological Model, B. Moore, S. Bertone, K. Mitchell, P. Rice, R. Neill

j. SFCTMP Overview Paper

k. Relocatable Window Model Overview Paper

l. Advanced Weather Analysis and Prediction System, J. Stobie, June, 1986

m. Mathur paper, 1983, Monthly Weather Review, McAtee et al, Oct. 1989, American Meteorological Society

n. Computer Models used by AFGWC and NMC for Weather Analysis and Forecasting, Tsgt. Richard J. Conklin, August 1992, AFGWC/TN-92/001

o. Map Projections and Grid Systems for Meteorological Applications, Dr. J. Hoke, Capt. J. Hayes, 2nd Lt. L. Renninger, AFGWC/TN 79/003, revised March 1985

p. Improved Point Analysis Model Users Guide, AFGWC/TN-91/001, February 1991

1.3 Terms and Abbreviations

3DNEPH - Three dimensional Nephanalysis
5LAYER - Five-Layer Cloud Forecast Model
AFGWC - Air Force Global Weather Central
AGL - Above ground level
AIREP - Aircraft Reports
AGRMET - Agricultural Meteorology Model
AGROMET - Agricultural Meteorology
ASDAR - Aircraft to Satellite Data Relay
ASPAM - Atmospheric Slant Path Analysis Model
AWAPS - Advanced Weather Analysis and Prediction System
AWS - Air Weather Service
BOGUS - Manual interactive modification of weather data
CPS - Condensation pressure spread
CPU - Central processing unit
DMSP - Defense Meteorological Satellite Program
DOF - AFGWC Mission Tailored Product Branch
DOM - AFGWC Meteorological Products Branch
DOS - AFGWC Special Projects Workcenter
ECMWF - European Center for Medium Range Weather Forecasts
EDR - Environmental Data Record
ETAC - Environmental Technical Applications Center
FAS - Foreign Agricultural Service

FNOC	- Fleet Numerical Oceanography Center
GADB	- Global Applications Database
GOES	- Geostationary Operational Environmental Satellite
GSM	- Global Spectral Model
GISS	- Goddard Institute for Space Studies
HIRAS	- High Resolution Analysis System
HRCP	- High Resolution Cloud Prognosis
IR	- Infrared
I T Z	- Intertropical convergence zone
km	- kilometers
LOWTRAN	- Phillips Lab Atmospheric Low Resolution Transmissivity Model
LSI	- Land/Sea Ice
mb	- millibars
METAR	- Meteorological Atmospheric Report
nun	- Millimeter
MSL	- Mean sea level
NCAR	- National Center for Atmospheric Research
NH	- Northern Hemisphere
NM	- Nautical mile
NMC	- National Meteorological Center
N O M	- National Oceanic and Atmospheric Administration
NSNBOG	- New Snow Bogus software
NWS	- National Weather Service
01	- Optimum Interpolation
OIVP	- Optimum Interpolation Vertical Profile
osu	- Oregon Stat8 University
PA	- Point Analysis
PBL	- Planetary Boundary Layer
PCOEF	- AGRMET precipitation coefficients
PL	- Phillips Lab (formerly Air Force Geophysics Lab)
PIBAL	- Pilot Balloon
PIREPS	- Pilot Reports
RTNEPH	- Real-Tim8 Nephanalysis Model
RAOB	- Radiosonde Observations
ROCOB	- Rocketsonde Observations
RECCO	- Aircraft Weather Reconnaissance
RWM	- Relocatable Window Model
RWAM	- Relocatable Window Analysis Model
SCIF	- Sensitive Compartmented Information Facility
SDHS	- Satellite Data Handling System
SESS	- Space Environmental Support System
SFCTMP	- Surface Temperature Model
SGDB	- Satellite Global Database

SLAM - Swedish Limited Area Model
SSM/I - DMSP Microwave Imager
SSM/T-1 - DMSP Microwave Temperature Sounder
SST - Station-to-Station Transfer
System A - A Unisys 1100/72 used to do preprocessing for the Cray
System 3 - A Unisys 1100/91 dedicated to classified processing
system 5 - A Unisys 1100/91 used for satellite and AGRMET processing
System 6 - A Unisys 1100/91 used for development and backup
TIROS - Television Infrared Observation Satellite
TOVS - TIROS Operational Vertical Sounder
TRONEW - Tropical Cloud *Forecasting* Model
USDA - United States Department of Agriculture
VP - Vertical Profile
WIPP - Weather Information Processing Program

SECTION 2

2.0 System Summary

2.1 Background

This project is an initiative supported by the Space and Missile Systems Center (SMC/IMO) that is designed to document the current system of models and data used by AFGWC/SYSM in meteorological analysis and forecasting. These models generate weather products used by military units worldwide.

AFGWC is divided into two divisions. The Operations Division (DO) supports AFGWC daily operations, while the Systems Division (SY) supports hardware and software development and maintenance. SYS is the Software Branch within the Systems Division, while SYSM is the Meteorological Models Workcenter within the Software Branch.

2.2 Objectives

This effort is intended to provide a basis for the proposed re-architecture of AFGWC systems. An initial objective is to document existing models, techniques, procedures, processes, and data-flows. An overview of SYSM models is provided at Figure 1. A general reference for the *SYSM models is in* reference n. To support this objective, this document was written in the form of a Functional Description (FD) (reference a). The Functional Description will then provide a basis for development of requirements for an upgrade of the facility hardware/software. Also, the FD will aid in the development of a Request *For* Proposals (RFP) and will provide information to contractors who bid on the proposed AFGWC upgrade contract.

2.3 Existing Methods and Procedures

2.3.1 Analysis Models

2.3.1.1 Snow Analysis Model (SNODEP)

SNODEP generates daily snow age and depth analyses. It has been operational since March 1975 for the Northern Hemisphere and October 1975 for the Southern Hemisphere. The snow analysis model uses the latest conventional observations (surface

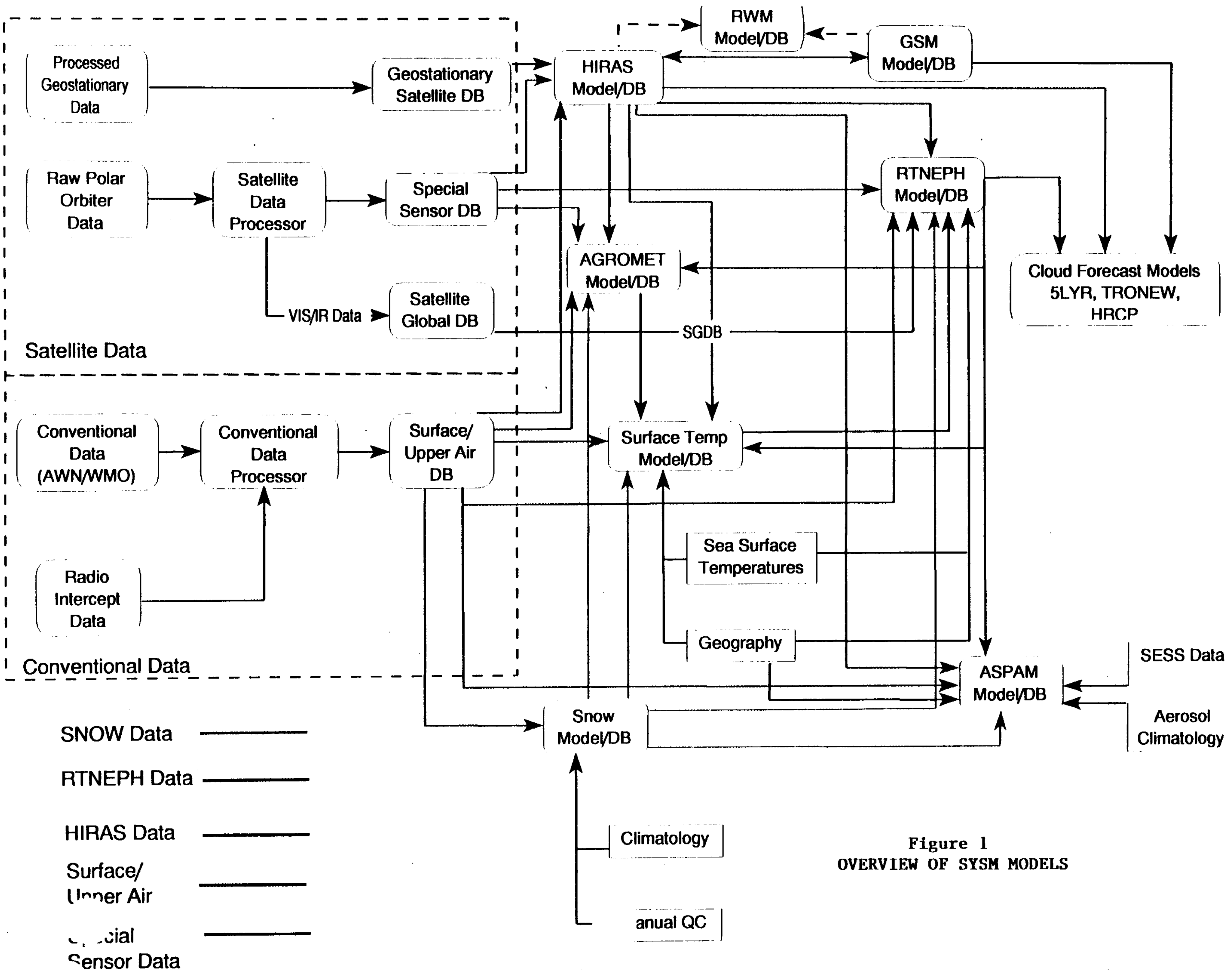


Figure 1
OVERVIEW OF SYSM MODELS

synoptic reports), snow and ice climatology, time continuity, and manual updates. This makes it possible to produce very good measures of snow extent and reasonable snow depth values at all grid points over the land and the ice-covered areas of the earth, regardless of the availability of surface observations. Refer to Figure 2 for a diagram of the SNODEP model.

The analysis grid used in SNODEP was originally designed for the AFGWC Three-Dimensional Nephanalysis (3DNEPH) Model. In August 1983, the 3DNEPH was replaced by the Real-Time Nephanalysis (RTNEPH) model; however, the same grid structure was retained. Each of the 64 3DNEPH/RTNEPH boxes contains 4096 grid points in a 64 by 64 array, resulting in a horizontal resolution of approximately 25 nautical miles (NM) (eighth-mesh).

The SNODEP model receives its inputs from:

a) Surface observations. The latest 24 hours of surface observations for each reporting station are used in the initial snow depth analysis. Snow depth reports for any hour in the 24-hour analysis interval are considered and are updated by additional snowfall data or decreased by calculated snow melt. If an actual snow depth is not reported, a 24-hour change is calculated using the six-hour snow accumulation, present weather, temperature, or state of the ground.

b) Land, Sea, and Ice Geography. The land/no-land geography is a "fixed" field (does not change). Sea ice information is manually added (bogused) to this field from weekly bulletins received from the Joint National Oceanic and Atmospheric Administration (NOAA)/Navy Polar Ice Center showing updated latitude/longitude coordinates of the ice. These data are reintegrated to form a Land/Sea Ice (LSI) geography field. This field is readily available as a part of the AFGWC nephanalysis geography database.

c) Continuity. The previous day's snow depth analysis is used for computing snow depth changes when normally reported depth observations are not available during the 24-hour period.

d) Snow Climatology. This consists of original data, a first-guess climatology field established by relating snow depth to other meteorological parameters by means of a multiple regression analysis, data manipulation (to handle zero snow

Snow Depth Analysis Model
(SNODEP)

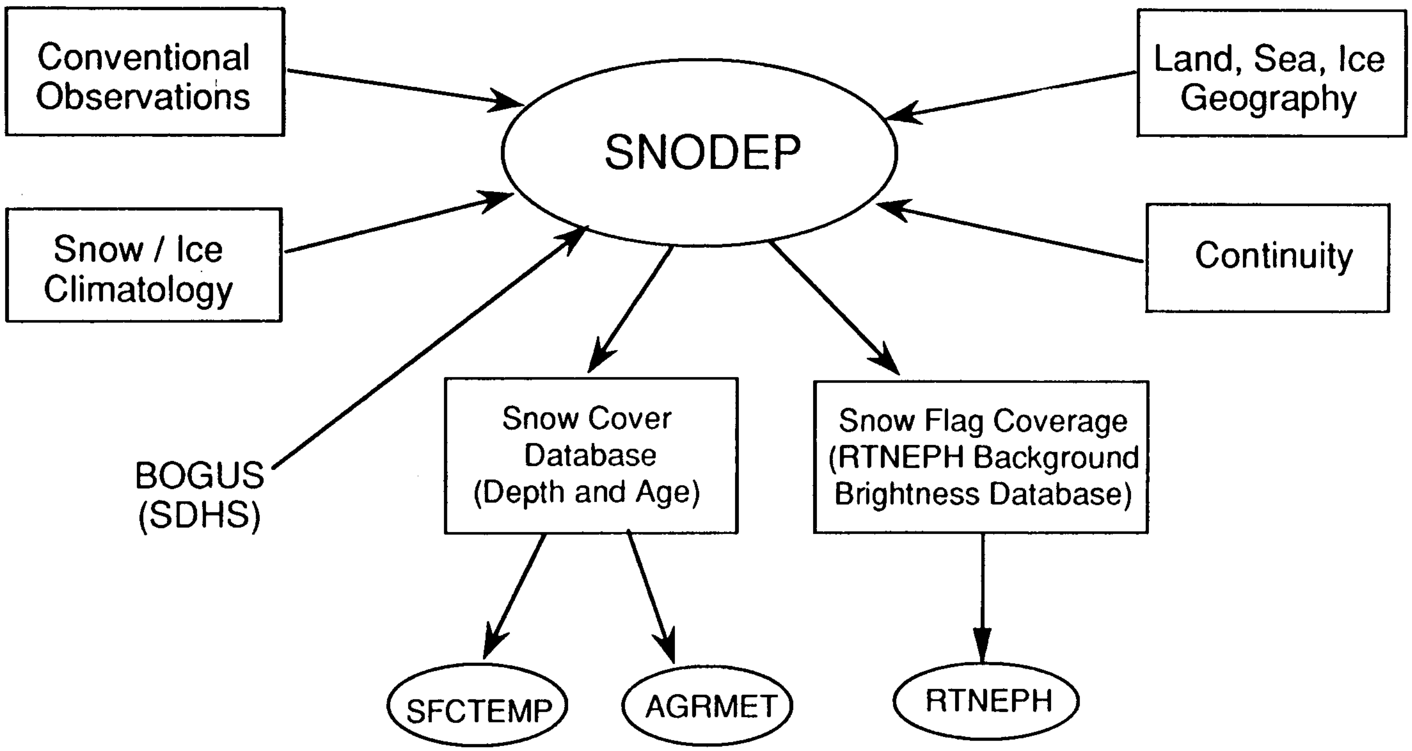


FIGURE 2

depth and to describe surface temperatures), and final climatology analysis. Snow climatology is used when snow reports have not been found in the surface regions database.

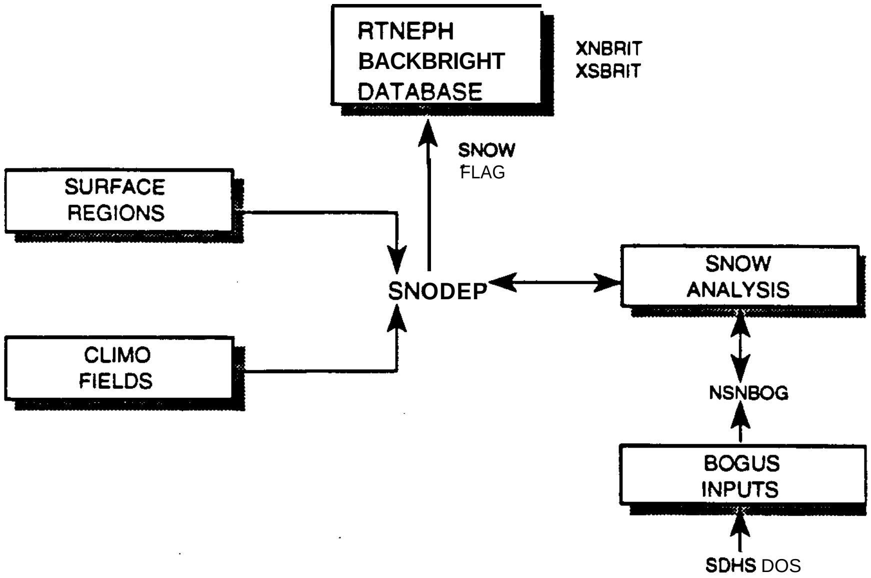
e) **Snow Bogus.** Snow depth, snow age, and ice data fields may each be changed manually when obvious errors are found in the analysis.

The analysis program produces a gridded-field representation from the snow depth information received as Dart of the surface synoptic observations. A basic assumption in the analysis routine is that a station report is representative of conditions at the four grid points around it. The station report snow information may be received by the analysis program in one of three possible forms: actual snow depth, new snow accumulation and snow melt. How the report is used in the analysis is determined by whether the grid point to which the report will be applied had its snow-depth value bogused in the previous three days. When a grid point is bogused, a bogus flag is set to one and it is incremented each day during its existence. The program is designed so that a bogused analysis value will be effective for three days, unless it is overridden by specific snow depth amounts.

In the absence of observations and bogused data, an alternate analysis scheme is employed. In this scheme, decisions are made dependent upon the values of yesterday's analysis and snow climatology. Snow age (in days) is calculated for each grid point where the snow depth is greater than one inch.

Output from SNODEP is used by the SFCTKP, AGRMET, and RTNEPH models.

At 14002, SNODEP is manually started on System 5 by the operator. It searches the previous day's observations from 13002 yesterday to 12002 today to make the analysis valid at 00002. When complete, the fields are sent to the SDHS where DOS analysts perform the snow bogus. The bogus inputs are sent back to System 5 where they are integrated into the Snow Database by the New Snow Bogus (NSNBOG) software. NSNBOG runs once a day. SNODEP runs on the Unisys 1100/91 in less than five minutes and requires less than 65K of memory. It is written in FORTRAN. The following diagram identifies the data flow.



XNBRIT and XSBRIT are RTNEPH background brightness databases.

<u>Model Strengths and Weaknesses</u>

<u>Strengths</u>
- Daily snow coverage is quite good

<u>Weaknesses</u>
- Present model requires much human intervention to maintain good quality
- No remotely sensed data are used to help in data sparse regions
- Ice coverage is a completely manual process

For more information on this model, see reference g.

A. Organization responsible: SYSM
B. Equipment: Unisys 1100/91 (Systems 5 and 3)
C. Input: Climatology database
Terrain database
Geographic database
Conventional observations
Geostationary satellite imagery and the SGDB are also used during the snow/ice bogus process

Output: Snow/Ice database on System 5 and 3

2.3.1.2 High Resolution Analysis System (HIRAS)

HIRAS is the primary analysis system in the Advanced Weather Analysis and Prediction System (AWAPS). It is based on a circa 1980 model from the National Weather Service (NWS). The main components of HIRAS are the first-guess model and an analysis model. The HIRAS analysis model is composed of two distinct modules: the surface module, and the upper-air module. The primary function of the surface module is to anchor satellite derived thicknesses to a 1000mb height field. The height/temperature soundings that are created by this process are then placed in the upper-air database. AGRMET and *SFCTMP* also use the surface analysis. The upper-air analysis provides all of the initial conditions for the Global Spectral Model (GSM).

The current version of HIRAS analyzes D-values, temperatures, horizontal winds for mandatory pressure levels from 1000 to 10 millibars (mb), sea-level pressure, and relative humidity (1000mb to 300mb). A D-value represents a deviation in height from the reference value for a particular level. HIRAS uses an optimum interpolation (OI) technique which produces the analyses. The 01 technique takes into account three factors: the distance between the observations and the grid point, the accuracy of the observing instruments, and the expected accuracy of the first guess. It uses inputs from surface observations, upper-air observations, and satellite soundings from the Defense Meteorological Satellite Program (DMSP) Microwave Temperature Sounder (SSM/T-1) and the TIROS Operational Vertical Sounder (TOVS). The first-guess model produces a six-hour or 12-hour GSM forecast which can then be used for a subsequent cycle's first-guess. Moreover, using information on the error characteristics of the observations and the first-guess fields, optimum interpolation can blend the first-guess with the observations to produce more accurate analyses.

HIRAS uses the LAT/LON database to store meteorological parameters at latitude/longitude grid points. Also, all data are stored at mandatory pressure levels. Meteorological data are stored in both spectral coefficient form and in a 2.5° x 2.5° latitude/longitude grid format (≈150 x 150NM) and then interpolated into the coarse mesh grid system. The 2.5° x 2.5° latitude/longitude includes analysis data for relative humidity, temperature, standard pressure levels, height *of* standard pressure levels, and the u,v wind components. The u,v component is a wind speed indicator; u represents wind speed in the east/west direction (+ for east, -for west) and v represents wind speed in the north/south direction (+ *for* north, - for south). It is updated several times each cycle by XIRAS. See reference d. Refer to Figure 3 for a diagram of the XIRAS model. XIRAS includes the following features:

a) Analysis is done on standard *pressure* surfaces in the vertical and on an equal area gaussian grid in the horizontal (Kurihara Grid).

b) Uses 01 as an objective analysis method, and a 30-wave GSM to produce a six-hour or 12-hour forecast used as a first-guess.

c) Directly analyzes five variables: heights, u and v wind components are analyzed using multivariate optimum interpolation. *Temperature* and relative humidity are analyzed using univariate optimum interpolation.

d) Other users of XIRAS data include the Relocatable Window Model (RWM), the Agricultural Meteorology Model (AGRMET), the Atmospheric Slant Path Analysis Model (ASPAM), the Surface Temperature Model (SFCTMP), the Xigh Resolution Cloud Prognosis Model (HRCP), the Global Spectral Model (GSM), and the 5LAYER cloud forecast model.

e) Surface HIRAS' primary function is to provide the 1000mb height field used to anchor satellite soundings. Surf ace fields are also produced. Surface XIRAS is a univariate analysis done on a latitude/longitude grid.

f) The actual upper-air analysis grid is lower in resolution than the 2.5° x 2.5° latitude/longitude grid.

g) The upper-air analysis is a transformation of the sum of R24 wave residual fields and R30 wave first-guess fields. The effective resolution of the upper-air analysis is between 24 and 30 waves.

h) The XIRAS analysis uses a three-dimensional 01. *For example,* a grid point at 500mb may use observations anywhere

High Resolution Analysis System
(HIRAS)

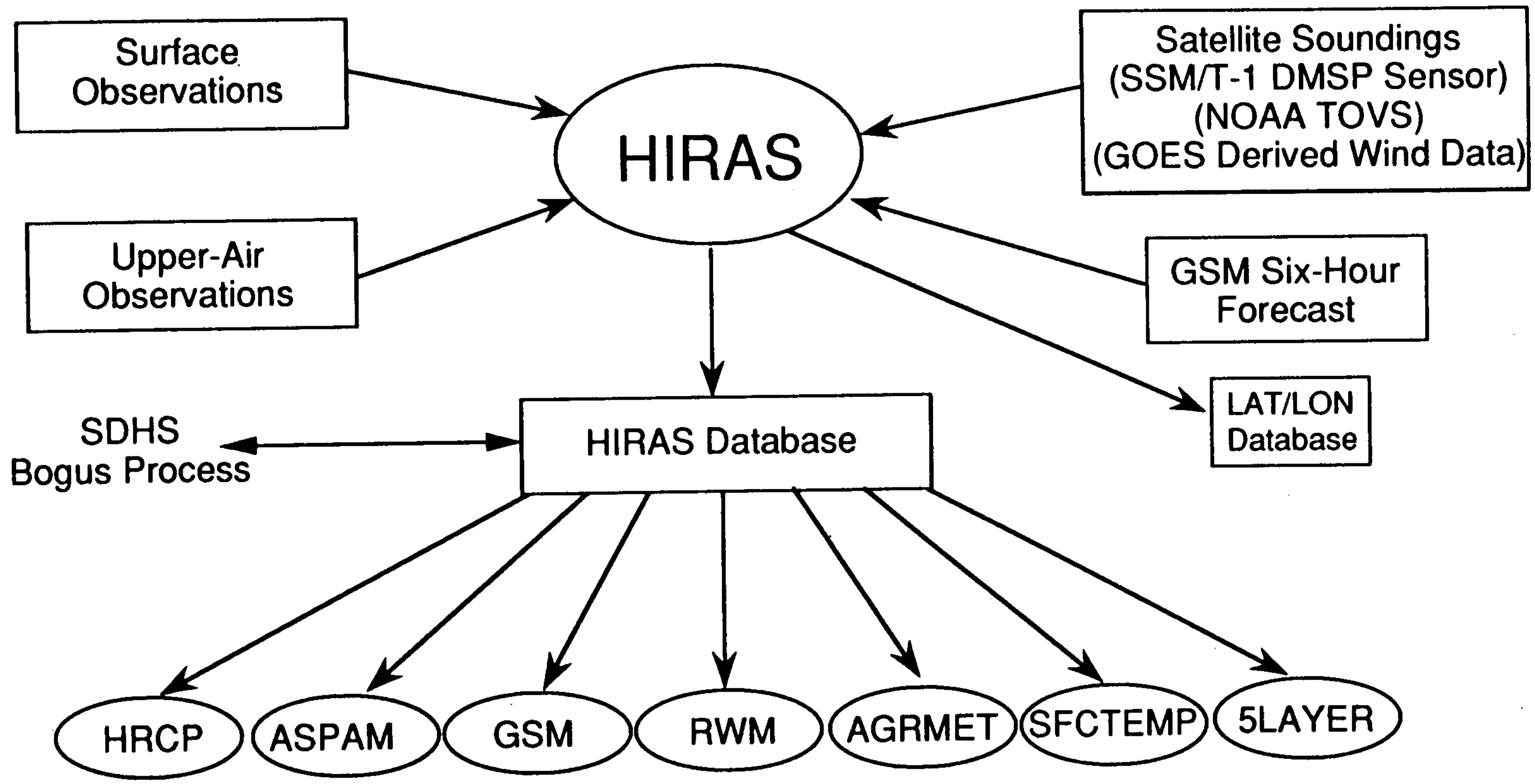


FIGURE 3

between 200mb and 1000mb. The only exception to this is above 100mb, where the OI only looks horizontally for observations.

i) HIRAS draws more for individual observations in data-sparse areas than it does in data-rich areas.

j) HIRAS compensates for instrument accuracy.

k) Upper-air wind and height analyses are multivariate everywhere except in the tropics.

1) Upper-air temperature and moisture analyses and all surface analyses are univariate.

m) The first-guess in the stratosphere (above 100mb) is the previous analysis.

n) The first-guess wind in the stratosphere is forced to be geostrophic.

o) HIRAS checks input observation data, in addition to those done by the AFGWC upper-air validator, when observations are placed into the database. Those checks are a gross check, which throw out input observations that deviate more than a specified amount from the first guess. A buddy check does a further examination of suspect observations that are not quite bad enough to be eliminated by the gross check.

Upper-air HIRAS runs twice per 6-hour cycle: once for input to the GSM, and again for the first-guess function. It takes about 35 minutes to run and generates data used as initial conditions for the GSM, and initial and boundary conditions for the RWM. The surface HIRAS is run three times per 6-hour cycle. The compute-intensive part of HIRAS is run on the Cray and the data assimilation and database writing part of HIRAS runs on a Unisys 1100/72 (System A), HIRAS is written in FORTRAN.

MODEL STRENGTHS AND WEAKNESSES

Strengths

a) High dependability. It has been around for so long that most of the bugs have been worked out. The hardware is also quite dependable.

b) Uses the SSM/T-1 database to provide observations over data-sparse areas.

c) Strong quality control check of input observations. Observations go through the AFGWC validator, HIRAS gross check, and HIRAS buddy check.

d) Frequent bogusing from the Meteorological Products Branch (DOM) eliminates many major synoptic-scale errors.

e) Runs within operational time limits on current hardware. Does its primary job quite well, providing initial conditions for the GSM.

Weaknesses

a) Error statistics for satellite data are incorrect. Observation Error Standard Deviation (OESDs) and horizontal error correlations of satellite sounding data are used in the OI analysis to weight input observations according to the expected accuracy of the data.

b) Radiation correction of sounding data is out of date. This affects the stratospheric analysis.

c) Terrain field is very smoothed (R24-wave). Large sea surface areas have elevations below sea level.

d) Analysis is done on 12 mandatory pressure levels rather than sigma levels. This keeps vertical resolution low.

e) Extremely low horizontal resolution (approximately R30-wave), matches the first-guess GSM.

f) The first-guess for the analysis done above 100mb is the previous analysis.

Note: A global data field can be represented as a series of waves using spherical harmonics. For an R30-wave model, this two-dimensional series of waves is rhomboidally truncated to 30 waves in one direction and 31 waves in the other direction.

See reference 1 for additional details.

A. Organization responsible: SYSW
B. Equipment: Unisys 1100/72 System A, Cray
C. Input: a. Upper-air and Surface Regions Database
- GSM First-Guess Coefficients (on pressure surfaces, a 6 or 12 hour forecast) *
- Radiosonde Observations (RAOB) data
- Geostationary Operational Environmental Satellite (GOES) wind data
- Surface observations
- Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) data (NOAA 11)
- DMSP SSM/T-1 Sensor (currently F10)

b. A "bogus" dataset created on the SDHS

Output: a. Coarse Mesh Database
- AFGWC Coarse Mesh Analysis
- Hemispheric Analysis
- Spectral Analysis

b. Latitude/Longitude (HIRAS) Database
- 2.5° x 2.5° Analysis Fields
- 2.5° x 2.5° Analysis Error Fields
- Analysis Coefficients (on pressure surfaces)*
- Analysis Error Coefficients (on pressure surfaces *

* Note: The coefficients in the input and output sections are not on a lat/lon grid, but are represented as spherical harmonic coefficients or spectral coefficients.

2.3.1.3 Real-Time Nephanalysis Model (RTNEPH)

The RTNEPH replaced the 3DNEPH as the AFGWC cloud analysis model in August, 1983. Just as its predecessor, the RTNEPH continues to blend high resolution satellite data and conventional data to perform an automated cloud analysis. The RTNEPH contains two major differences from 3DNEPH: the database definition of the vertical structure, and the addition of diagnostic information. RTNEPH employs four floating vertical layers versus the 15 fixed layers in 3DNEPH. This allows a greater vertical resolution as cloud bases and tops are sharply defined and removes constraints on applications that are sensitive to cloud layer definition. The addition of diagnostic information allows better quality control techniques and more detail for users of the database.

The RTNHPH cloud analysis model uses primarily single 'channel infrared (IR) data in addition to some visual (vis) data, conventional weather observations, snow data, surface temperatures, and upper-air analyses to construct the final database. The RTNHPH employs a "threshold" method to analyze satellite data. Using the surface temperature database, background brightness, and other empirical corrections, the RTNHPH decides on a pixel value for the "cloud/no-cloud" threshold. Any pixels which have a value that indicates it is colder (brighter) than the threshold are recorded as indicating a cloud is present. A "clustering" technique determines cloud layers and amounts. This is done on a quarter-mesh (25NM), polar stereographic grid with up to four floating cloud layers at each grid point.

The model determines the cloudy/clear grayshade cutoff, eliminates clear pixels, clusters cloudy ones into layers, and computes layer amounts. This is done mostly with IR data although the visual data is used to adjust total cloud and to help determine cloud type. If conventional data is newer, it will be used for low cloud detection. The model runs on System 5 immediately after receipt of new satellite imagery. The primary use of the RTNEPH database is to initialize the five-layer and tropical cloud forecasting models (5LAYER, TRONEW), and the HRCP cloud forecast model.

The input data for RTNEPH have characteristics dictating a compromise between fine and coarse resolution. The satellite data used by RTNEPH are taken from the AFGWC Satellite Global Data Base (SGDB). The SGDB incorporates visual and infrared imagery from the DMSP satellites and infrared imagery from NOM weather satellites. Raw DMSP satellite data (1.5NM resolution) is processed to result in smoothed grayshade values and is stored in the SGDB at a resolution of 3NM.

To get a representative sample of cloud layers, a set of points must be combined. RTNEPH currently uses a 16 x 16 array (i.e., four eighth-mesh points) of SGDB values. If too few points are combined, the analysis loses the ability to determine cloud layer structure. If too many points are combined, however, the analysis loses the fine detail provided by the satellite data. Conventional observations such as surface reports and RAOBS are also used as input to RTNEPH. Conventional data is updated every hour. These observations typically describe an area with a radius of 20NM to 50NM. If the resolution of the grid is too coarse, many conventional observations may occur within a grid box causing some to be discarded or merged. However, too fine a grid would let the conventional data distort the analysis provided by the satellite data.

The data in RTNEPH are arranged vertically in up to four cloud layers at each point. Each layer has information on cloud amount, type, base, and height. The layers are sorted by cloud base, with the highest base in layer one. The layers can overlap, and the top and bottom boundaries are not fixed. See Figure 4.

Basic RTNEPH Functions

There are six basic modules within the RTNEPH system. The three primary modules are:

a) Satellite processor, which performs a cloud analysis based on satellite data only and produces an intermediate database.

b) Conventional processor, which builds an intermediate analysis based solely on conventional data (surface observations and rawinsonde observations.

c) Merge processor, which merges the satellite and conventional analyses to form the RTNEPH database.

The above three modules make up the core of the RTNEPH system. The system is completed by adding the following three support modules:

a) Bogus processor, which allows manual modification to correct deficiencies in the automated analysis.

b) Display processor, which allows specific parameters to be displayed in formats usable to meteorologists.

Real-Time Nephanalysis Model
(RTNEPH)

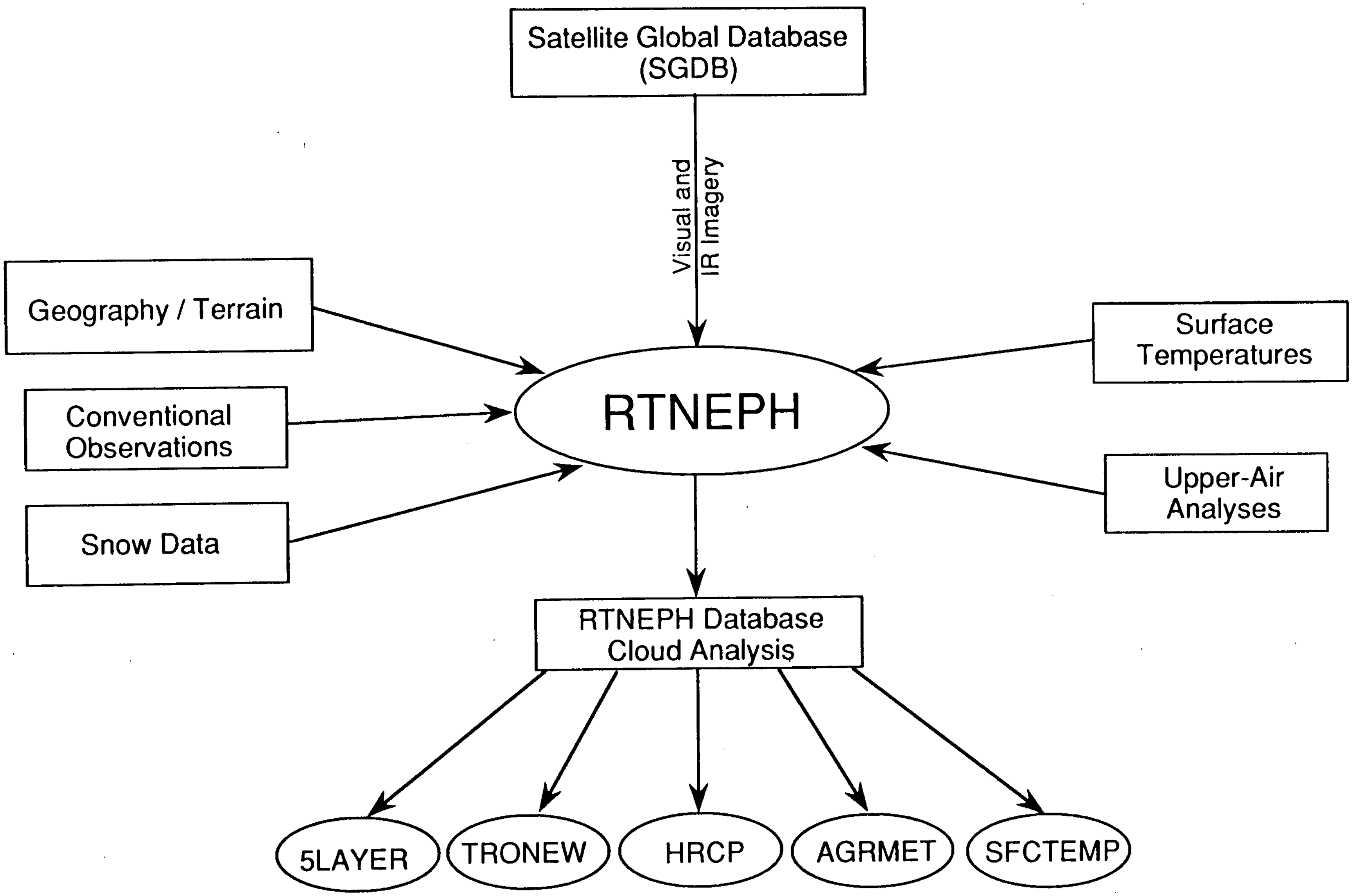


FIGURE 4

c) Driver module, which schedules the execution of the Satellite and Merge Processors based on availability of the data and computer resources.

There are databases which provide direct data inputs or provide data supporting the analysis of conventional or satellite data. Examples include:

a) *Geography/Terrain* database, which includes terrain heights as well as indicators of geography type (e.g., land, water, coast, ice-covered water) for the eighth-mesh grid.

b) Satellite Global Database, the array of satellite data represented by grayshades for three nautical mile resolution pixels.

c) Surface temperature database, which contains surface temperatures at eighth-mesh for the infrared satellite data to use for determining cloud-covered pixels.

d) Upper-air temperature database, used to calculate the tops of cloud layers derived from infrared satellite data. The resolution is 200NM.

e) Conventional reports database containing the reports used in the conventional processor.

f) Snow data from the SNODEP database.

g) HIRAS and GSM (lat/lon database) also provide data for input to the RTNEPH.

Operating Modes

RTNEPH operates in one of three modes in the AFGWC production cycle: sprint, non-sprint, and update (Synoptic). Each mode has a specific purpose.

The Sprint Process.

The sprint cycle is designed to incorporate a quarter-orbit of satellite data as quickly as possible into the RTNEPH and then into the HRCP cloud forecast model. The sprint cycle is initiated by the receipt of a quarter-orbit of data into the AFGWC computer system. The data are mapped into the SGDB and then the RTNEPH Satellite and Merge Processors process the RTNRPH boxes containing new satellite data. The RTNRPH output is manually quality controlled (bogused) and, if needed, changes are made by the bogus process. The bogus process uses all available satellite imagery (DMSP, NOM, and GOES), conventional data, and analyst experience to accomplish the RTNEPH bogus. The analyst may make adjustments to the automated analysis of total cloud, layered cloud amounts, and/or cloud heights. The updated RTNEPH analysis is sent to System 3 to start the forecast part of the Sprint process (HRCP). This process is outlined in Figure 5 (Sprint Process).

The Non-Sprint Cycle

The non-sprint cycle is similar to the sprint cycle except the timeliness, manual quality control, and immediate cloud forecast model input restrictions are lifted. It also operates on a quarter-orbit basis. If the satellite data does not go through the sprint cycle, it does not go through the RTNEPH bogus process but does go into the SGDB. Though the non-sprint cycle is not as time critical as a sprint, it is extremely important for the complete database.

The Update Cycle

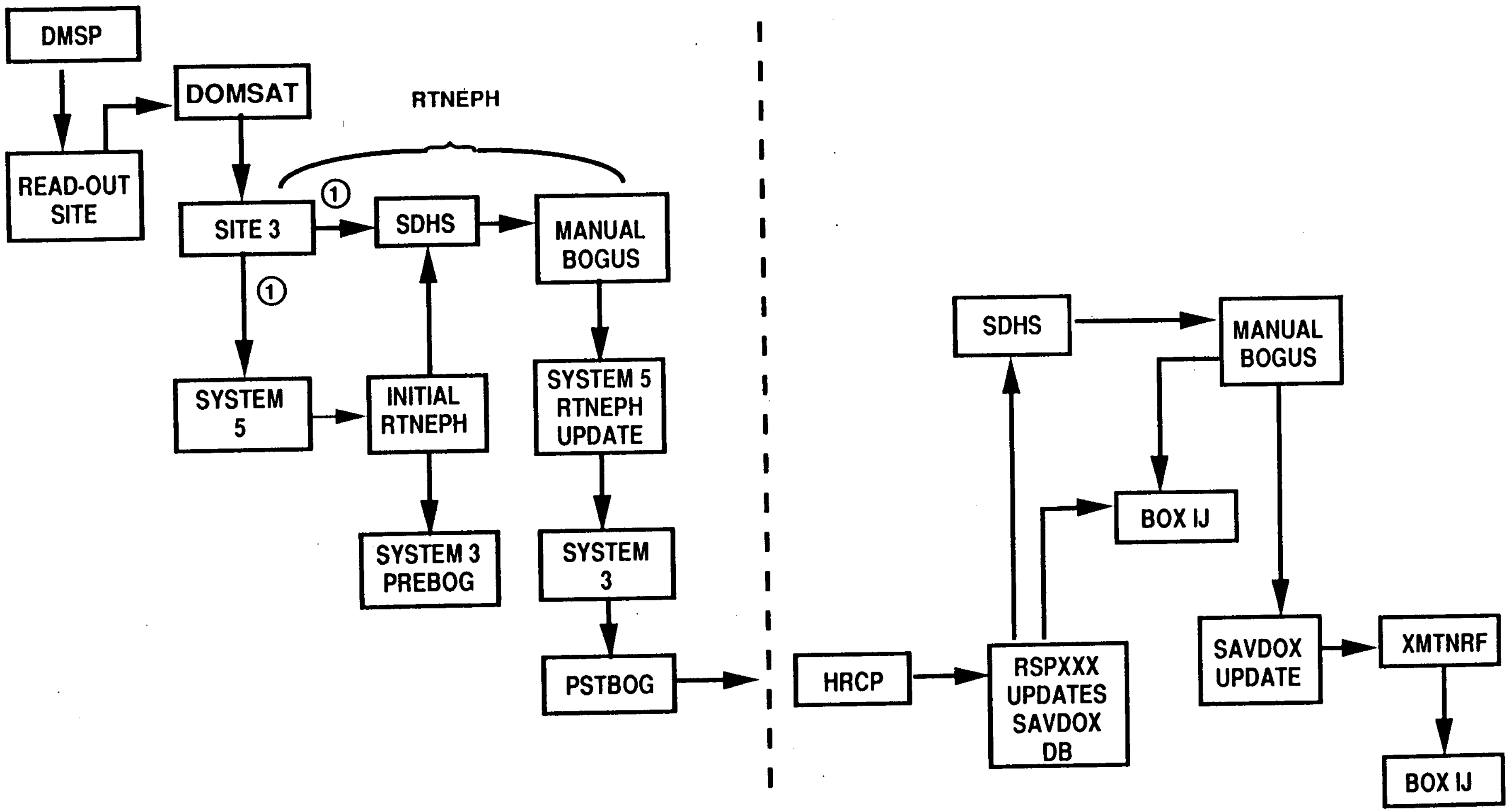
The purpose of the update cycle is to incorporate as much data as possible every three hours before making a "synoptic" copy. Unlike the sprint and non-sprint cycles, the update cycle operates on a hemispheric basis. All remaining unprocessed quarter-orbits from the last update cycle are processed in the Satellite Processor. Then this data is merged with the most recent conventional data. Finally, a snapshot of the database is created to make the synoptic copy. The northern update is built approximately two hours after data time (00002 built at 02002) and the southern update is built three hours after data time.

MODEL STRENGTHS AND WEAKNESSES

Strengths

a) The model is fast. It can process a quarter-orbit in

Sprint Process



① = Happens simultaneously

FIGURE 5

about five minutes on the Unisys 1100/91 (System 5).

b) The "total cloud" analysis is accurate about 80-85% according to limited, but detailed verification. (ref. CMEP)

c) The model is written in *FORTRAN 77.*

d) The model is flexible and can process either IR or both IR and visible data depending on data availability and time of day. Incorporating visible data enhances the quality *of* RTNEPH's total cloud cover output.

e) Allows manual modification, if needed, to improve in weak areas.

f) Incorporates non-satellite weather analyses (primarily surface observations) when available and merges these sources with satellite observations.

g) Can be tuned to account for both regional and seasonal variations affecting its performance. SYSM performs routine quality control on model output to identify the need for tuning.

<u>Weaknesses</u>

The RTNEPH model has some weaknesses which are often caused by the model's inability to accurately determine which pixels are above or below its cloud/no-cloud threshold. Generally, an attempt is made to compensate for the weaknesses by doing a manual bogus on areas where the model is known to have problems. The known weaknesses are:

a) Detection/interpretation of low clouds (thresholding breaks down *over snow or very* cold background *scenes).*

b) Thin cirrus detection.

c) Clouds along coastlines.

d) Interpretation of cloud layer amounts, types, and especially precipitating clouds (lack of microwave algorithms *and/or* data to see through clouds, and weaknesses in grayshade variance algorithms).

e) Single channel (IR) satellite analysis at night.

f) Mislocated fields (software geolocation errors, satellite hardware precision limitations, time difference between measurement and valid analysis time; combined, these errors are on the order of eighth-mesh).

The output RTNEPH database is used by the 5LAYER, TRONEW, HRCP, AGRMET, and SFCTMP models.

For additional information, see the RTNEPH database description in Appendix B and the document in reference c.

A. Organization responsible: SYSM
B. Equipment: Unisys 1100/91 (Systems 5)
C. Input: Satellite Global Database Cloud Data
Geography/Terrain data
Conventional Observations
Snow data
Surface Temperature
Upper-air analysis data
Special Sensor database
HIRAS database
GSM lat/lon database
Output: RTNEPH Cloud Analysis database

2.3.1.4 Surface Temperature Model (SFCTMP)

The Surface Temperature Model is designed to analyze and forecast (short-range) worldwide surface temperatures at 25NM grid points (eighth-mesh) and three-hourly intervals. Temperatures are modelled at the earth's surface (skin) and at shelter height (two meters).. It was developed at AFGWC and became operational in April 1991. The Data Format Handbook contains the only current description of the program's file interface. Over land, the model produces first-guess temperature analysis and data error characteristics, applies an 01 Cressman (point) smoother to the analysis, then makes a forecast and horizontally smooths the fields to reduce errors. Skin temperatures are a byproduct of shelter temperatures over land.

Over water, the Navy data (see below) is interpolated to eighth mesh format. Skin and shelter height temperatures are identical (assumes the temperature gradient is negligible). Also, 3 and 4.5 hour forecast temperatures are identical to the analysis for each cycle (assumes negligible temperature evolution over this time scale). SFCTMP uses a truncated version of the Oregon State University Planetary Boundary Layer model: It uses only one atmospheric layer and parameterizes temperatures above that level.

The model uses external input sea surface temperature data from the Navy (Fleet Numerical Oceanographic Center) at a grid resolution of 200NM (whole-mesh). Internally at AFGWC the model uses data from the conventional observations database (humidity, observed temperatures), RTNEPH IR and Special Sensor Microwave Imager (SSM/I) data, HIRAS wind data, GSM database (surface temperature), the Snow/Ice database (used to determine if the area is covered by snow), and the previous SFCTMP three hour forecast. Conventional observations originate externally, but are revalidated internally. Also, terrain, geography, cloud cover (heating rate), AGRMET actual and potential evapotranspiration, and soil moisture data play a supporting role.

The model outputs 25NM (eighth-mesh) worldwide surface temperatures at analysis time, a three hour forecast, a 4.5 hour forecast and some error statistics. The temperatures are in Kelvin with an accuracy 2.5° to 3° near conventional observing sites. Water accuracy is defined solely by Navy data quality. Conventional observations are used as ground truth. The forecasts are for both skin temperature (surface) and shelter height. The output is stored in the Northern Hemisphere forecast database (XNSFCT) or the Southern Hemisphere forecast database (XSSFCT). Later the surface temperature data is used by RTNEPH. This a very important model and is considered to be the "right arm" of RTNEPH. The Environmental Technical Applications Center (ETAC) archives the SFCTMP analysis data.

The model runs every three hours on System 5 starting at 0130Z (about 1.5 hours after conventional data becomes available). HIRAS/GSM data is available every other cycle. The Northern Hemisphere runs one hour ahead of the Southern Hemisphere. The runs take about 45 minutes for the Northern Hemisphere and 30-45 minutes for the Southern Hemisphere. SFCTMP is written in FORTRAN 77 and runs on a Unisys 1100/91 under the EXEC operating system. See Figure 6 and reference j.

Surface Temperature Model
(SFCTEMP)

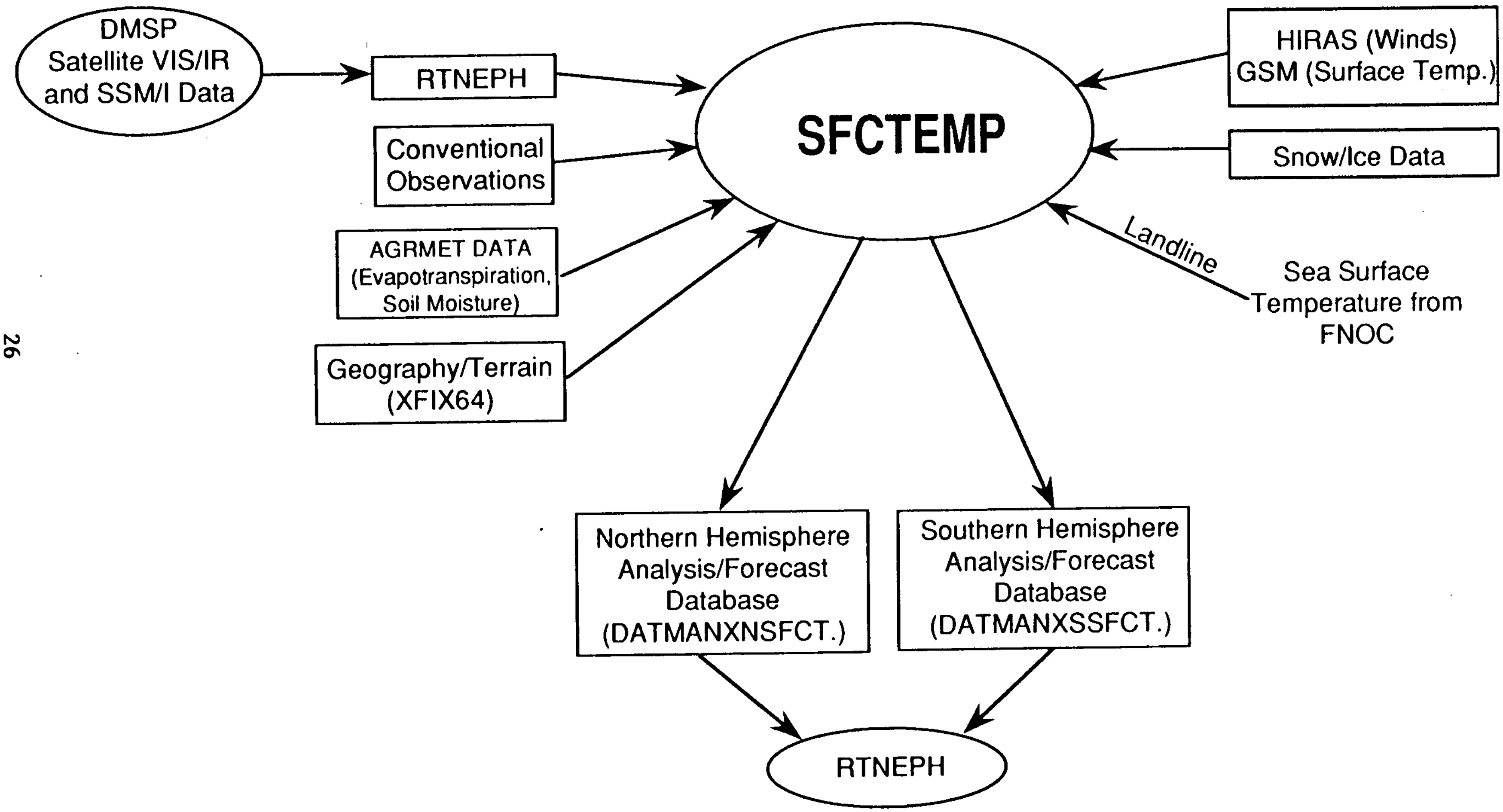


FIGURE 6

MODEL STRENGTHS AND WEAKNESSES

Strengths

a) It is a modern robust model (e.g., it has several data sources and can run if data is denied).

b) It has a boundary layer process to model low layer (two meters) and a soil hydrology model to handle moisture and sun heating on the surface.

c) The model runs even when denied current data. It can use previous data. However, if denied all outside data for more than a couple of cycles, the output would start to degrade.

Weaknesses

a) It performs poorly for Greenland.

b) A weakness in AGRMET shows up as a discontinuity in SFCTMP .

c) Data is sparse in some areas.

d) The whole mesh to eighth-mesh interpolation over ocean areas is a weakness.

e) Errors tend to grow without new data observations.

f) HIRAS data is interpolated from 3/4 mesh to 1/8 mesh

g) The model takes a relatively long time to run and uses a large amount of memory.

A. Organization responsible: SYSM
B. EquipmentUnisys 1100/91 (Systems 5)
C. Input: RTNEPH Database
SSM/I Data
Conventional Observations
AGRMET Data

Geography/Terrain Data
HIRAS wind data
GSM surface temperature data
Snow/Ice data
Sea Surface Temperatures from FNOC

Output: Hemispheric Surface Temperature Analysis Database

2.3.1.5 Agricultural Meteorological (AGRMET)

The AGRMET model was developed to provide the best possible agricultural meteorological (AGROMET) analysis from available AFGWC databases. It is a diagnostic model (not predictive) and provides worldwide analysis at a spatial resolution of about 25NM (AFGWC eighth-mesh grid).

Because of its access to worldwide weather data, AFGWC developed an agrometeorological data assimilation model in 1974 and began providing this information to the USDA's Foreign Agricultural Service (FAS). This enabled the FAS to run crop yield prediction models for major grain growing regions of the world, thereby keeping the US government, and interested factions of the US economy, informed about the status of world grain production. In 1984 the decision was made to redesign and expand the data assimilation model. The effort was extensive and the new model went on-line in April 1990.

The model achieves its purpose by using a new radiation scheme and a new soil hydrology scheme which are essentially the core of the AGRMET model. The radiation scheme was developed at AFGWC based on work done by Dr. Shapiro, Dr. Wachtman, (Air Force Geophysics Lab, 1987) and Dr. Idso (U.S. Water Conservation Lab, Phoenix, Az., 1981). The soil hydrology scheme was developed by Oregon State University and adapted for AFGWC's use by the Phillips Lab (PL/LY). The soil hydrology scheme (from the OSU Planetary Boundary Model) ingests AFGWC regions and fields data and radiation-scheme data and then generates 19 crop, soil, and meteorological-dependent AGRMET parameters at 25NM resolution for all major landmasses around the globe (in 58 of the 128 eighth-mesh RTNEPH boxes). The FLUX3 Program is the heart of the soil hydrology algorithm and is very advanced.

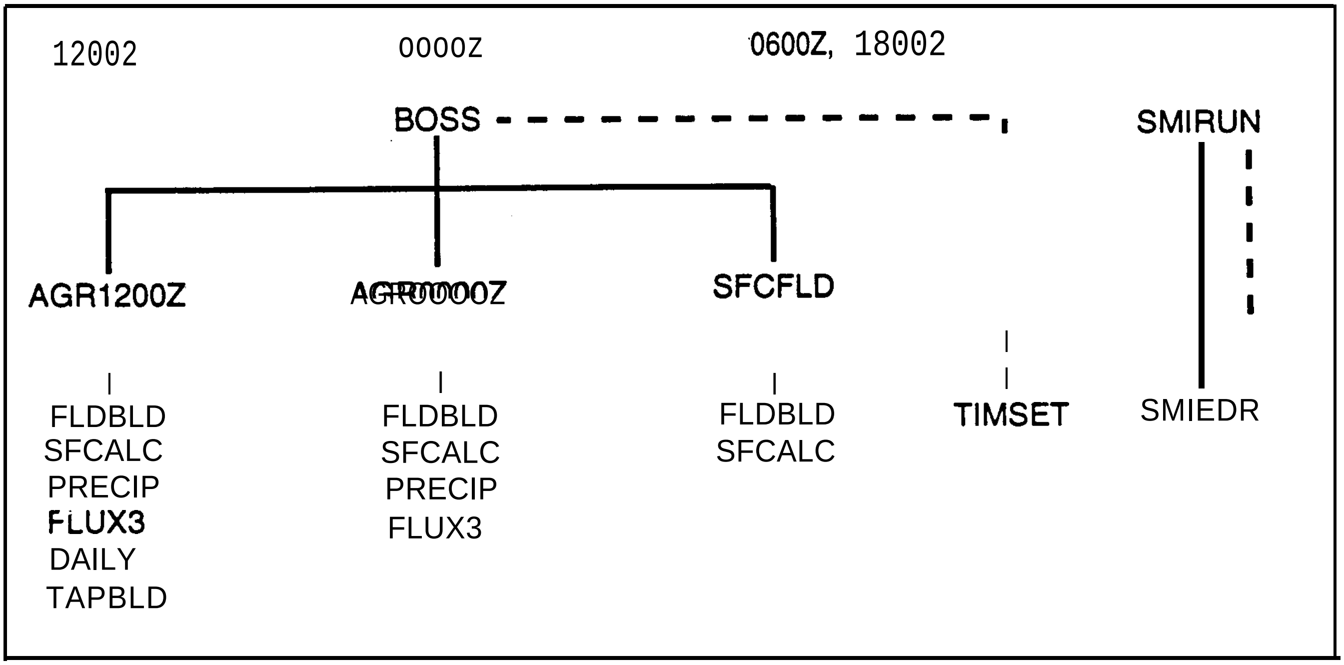
The model also uses an optimum interpolation technique for folding observed meteorological data into gridded meteorological analysis (first-guess fields), significantly improving the accuracy of the analysis. *For* example, HIRAS is used as a first-guess and then observations are laid on top and blended into the field. In addition, the model has a precipitation analysis scheme which uses several input sources to calculate precipitation amounts over heavily populated as well as remote areas of the globe.

The model has algorithms for the calculation of the phenological stage of four major grain crops: winter wheat, spring wheat, corn, and rice. Dual crops in the same area are not modeled. The model assumes a single crop per year and that the same conditions exist for the entire 25NM x 25NM grid cell. This includes such things as soil type, precipitation, and crop type. This is a coarse assumption in the agricultural meteorological community. The model essentially assumes what atmospheric condition8 would allow at that point and no human or urban effect8 are taken into account.

Runstream and Add-Element Descriptions

The BOSS runstream executes TIMSET (see descriptions below for the programs mentioned in this section) and then determines which add element (add-elt) is added. If the latest HIRAS database is 00002, AGROOZ will be added. If the latest HIRAS time is 12002, AGR12Z will be added. If the HIRAS time is 0600Z or 18002, SFCFLD will be added. BOSS is started by the System 5 operator at approximately 0355Z plus every 6 hours, after System 5 receive8 the HIRAS data. STORUA is the receiving program on System 5 for HIRAS data. The program is completely automated with the exception of the operator starting the BOSS runstream and tape handling. The following diagram shows the sequence of AGRMET's Execution Control System.

Program **Execution** control System



The **SMIRUN runstream** executes SMIEDR. It is started by the System 5 operator at about 0030Z plus every three hours.

Program Descriptions

1. **TIMSET** Program. **TIMSET** retrieves the **most** recent **julian** hour cycle of the **HIRAS** database and the last **time** FLDBLD was executed and sets the last third of the condition word. The condition word is then used in runstream BOSS to determine which add-elt to add (which **programs** to execute) for the given time. **TIMSET** is executed every six hours.

2. FLDBLD Program. FLDBLD builds data files containing eighth-mesh polar stereographic surface and upper-air **meteorological** data fields. The files cover 58 major landmass RTNEPH boxes. FLDBLD is executed every six hours.

3. *SFCALC* Program. *SFCALC creates* parameter fields for the surface needed by FLUX3 and DAILY using output from FLDBLD and observations from the Surface Regions Database. *SFCALC is*

executed every six hours.

4. PRECIP Program. PRECIP generates three-hourly precipitation amounts from observations and precipitation estimate sources for use by FLUX3, and 12-hourly amounts for use by DAILY. PRECIP is executed every twelve hours.

5. FLUX3 Program. FLUE3 operates the radiation and soil hydrology schemes. It processes through four three-hourly periods in one hour time steps. FLUX3 is executed every twelve hours.

6. DAILY Program. DAILY builds 24-hour amounts from 12-hourly amounts for assorted parameters stored in various data files by the other programs. The daily amounts thus collected and calculated are written to the AGRMET database. DAILY is executed every 24 hours between 1600Z-1900Z.

7. TAPBLD Program. TAPBLD retrieves data from the AGRMET database and writes it to tape for use by external customers.

a. SMIEDR Program. SMIEDR retrieves the latest SSM/I rain rate Environmental Data Records (EDRs) and writes them to a file for use by the PRECIP Program. SMIEDR is executed every three hours.

Databases Used

The AGRMET model uses several databases resident on the AFGWC systems. They are listed below.

1. AFGWC Surface Regions Database. Provides global data from surface meteorological observations. AGRMET uses surface temperatures, dew point temperatures, wind speeds, and precipitation amounts.

2. HIRAS Database. Provides 150NM resolution gridded global analysis of the atmosphere using Optimum Interpolation methods. HIRAS provides first-guess fields of temperature, D-value, relative humidity, and surface wind speed. AGRMET uses five parameters from four levels.

3. SSM/I Database. Provides SSM/I data at eighth-mesh resolution, worldwide. AGRMET uses EDR rain rates in millimeters

per hour (mm/hour).

4. Synoptic RTNEPH Database. Provides cloud amounts and cloud types at eighth-mesh resolution, worldwide. AGRMET uses both to estimate precipitation.

5. Snow Analysis Model Database. Provides snow depths and age at eighth-mesh resolution for those RTNEPH boxes where snow is possible. AGRMET uses snow depths only.

6. Hemispheric Fixed Fields Database (XFIX64). Provides terrain heights and a crude geography flag (land, water, or coast) at eighth-mesh resolution, worldwide. AGRMET uses both.

7. AGRMET Database. Contains seven days of 15 daily agricultural meteorological values that are accessed and written to tape by TAPBLD in groupings of two-days, three-days or seven-days, for shipment to the AGROMET customers.

<u>Files Used</u>

The AGRMET model uses data files resident on System 5 to store meteorological information and program control data. These files are:

1. CONTROL File. This file allows a programmer to change weighting factors. It also contains point-processing switches, box-processing switches, and program run times.

a. PRMSET File. This file allows a programmer to alter the meteorological constants used in the soil hydrology scheme. The file is divided into soil-dependent and vegetation-dependent parameters and each Dart is accessed directly.

3. MERGWT File. This file allows a programmer to alter how much real precipitation and how much estimated precipitation is used to create the merged precipitation amount for a given point.

4. SOILTYPE File. This file contains the predominant soil type for all eighth-mesh grid cells (the 25NM x 25NM area surrounding a grid point) which correspond to major landmass points on the globe. These data are used to determine soil-dependent parameters in the soil hydrology scheme. Soil data were derived from a 1° x 1° soil data set developed by Zobler at

the Goddard Institute for Space Studies (GISS). The data contains seven mineral soil textures and an organic soil type. The OSU soil hydrology algorithm is dependent on knowing the drainage characteristics of soils.

5. CROPTYPE *File.* This file contains the customer requested crop type (normally the predominant crop type) for all eighth-mesh grid cells which correspond to major landmass points on the globe. For regions with no crops, the types were derived from a 1° x 1° data set developed by Elain Matthews at the GISS. These data are used to determine the vegetation-dependent parameters in the soil hydrology scheme.

6. Daily Plant Phenology *Files.* These files contain the phenological stage (in photothermal units) of the crop at each major landmass point with a non-natural vegetation type. The phenological stage values are crop-dependent and are reset to zero at the end of each growing season.

7. BOTTOM-ST File. This file contains soil temperatures at three meters deep (the model's bottom boundary). These data are actually mean annual air temperatures. They are used because three meter soil temperatures are fairly invariant and because the soil hydrology scheme calculations are made far from this boundary.

a. SNDEP File. This file contains the snow depths at each point at the end of each 12 hour execution of the FLUX3 program. It is used to initialize subsequent execution of the FLUX3 program when the XSNDEP database has not been updated in the interim. Since the XSNDEP database is normally updated once a day, it is expected that this file will be used every other 12 hours.

9. PCOEF File. This file contains precipitation coefficients (precipitation rates in mm/hr). The coefficients are stratified by cloud amount and type, latitude band, longitude interval, and time of day. They are refreshed continuously and are a source of estimated precipitation rates when the only "observed" data available at a grid point are cloud type and amount.

10. Daily Snow Depth Files. These files contain snow depths retrieved from the XSNDEP once a day. They are needed

because the database only retains two days of snow depths and the AGRMET model needs up to seven days of data on certain days. In the event the XSNDEP database is corrupt or a data retrieval attempt fails, the daily data are obtained from the SNDEP file.

11. Planting and Harvesting Files. These files contain the limiting planting and harvesting dates (in Julian date) for various crop types.

12. SMIEDR *Files.* These files contain SSM/I rain rates and point times extracted from the SSM/I database.

13. *First-Guess* Fields Files. These files store the analyzed first-guess fields extracted from HIRAS.

14. Intermediate Analysis Output Files. These files store the analyzed data fields generated by and used by various parts of the AGRMET model.

15. Daily Statistics Files. These files contain model statistics from the SFCALC, PRECIP, and DAILY programs. A file will contain statistics for that day's processing.

Model Outputs

The AGRMET database contains seven cycles of northern and southern hemispheric AGRMET data. A cycle consists of 15 weather parameters. The following is a list of these parameters which are stored in the database daily:

1. 24 hour actual evapotranspiration
2. 24 hour potential evapotranspiration
3. 24 hour average soil moisture (top layer)
4. 24 hour average soil moisture (bottom layer)
5. 24 hour average soil temperature (top layer)
6. 24 hour real precipitation (observed)
7. 24 hour estimated precipitation
a. 24 hour merged precipitation
9. Daily mean temperature
10. Daily maximum temperature
11. Daily minimum temperature
12. Relative humidity at daily minimum temperature
13. 24 hour summed infrared radiation
14. 24 hour summed solar radiation

15. 24 hour summed wind

In addition to storing AGRMET output in the AGRMET database, data are also stored in the "first-guess fields" files. The actual evapotranspiration and potential evapotranspiration are also used by the *SFCTMP* Model.

The only external output from AGRMET are the tapes that are generated and sent to the customer. The Monday, 12002 run takes the longest time to process because it produces four tapes (three seven-day tapes, and one three-day tape). This process takes about two hours of wall-time with approximately one hour of central processing unit (CPU) time. The Tuesday, 12002 run is shorter (50 minutes wall-time with approximately 30 minutes CPU time) because no tapes are generated. On Wednesday, one tape is generated which takes about 90 minutes with approximately 50 minutes of CPU time. The average daily CPU time is about one hour.

The formal verification of the AGRMET model was completed by AGROMET customers. Problems were noted with precipitation estimates in data sparse regions and corrections *were* made to the code. *More* modifications are being designed to correct this problem. Some of the stated requirements for AGRMET are not realistic. There is quite a bit of spatial and temporal variability in a 25NM x 25NM box. Most of the accuracy requirements are supplied from customer feedback which indicates whether the data was valid or not.

Work is currently being done on a quality control program. There is a QCPRINT which has information on each point and is used for examining trends. Any rewrite should include a test mode. Currently, there is a FLUX3 test driver *for* checking out algorithms. Also, no in-house data analysis is done.

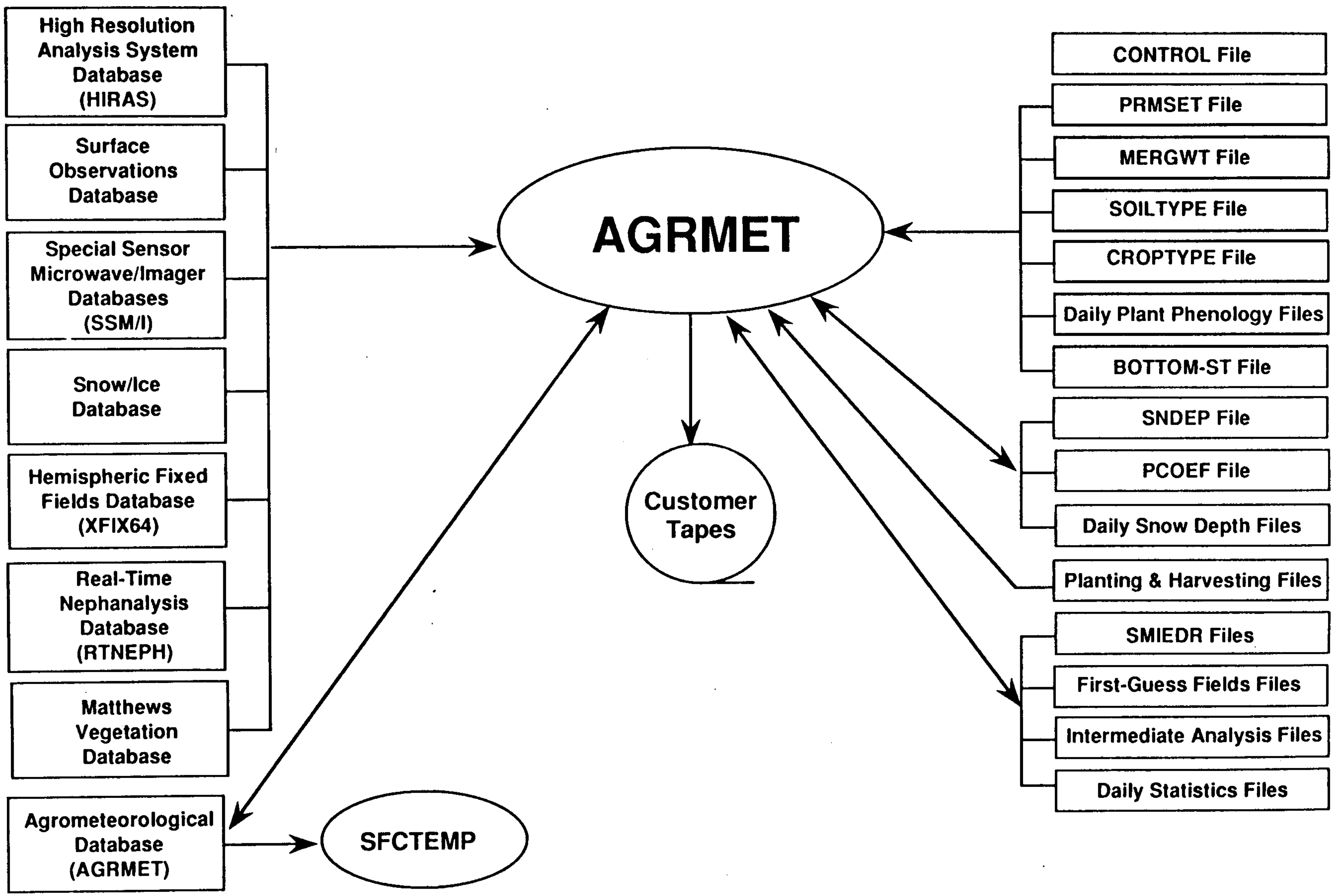
The AGRMET model is written in *FORTRAN 77.* It runs on the System 5 Unisys 1100191 with the EXEC operating system. See Figure 7.

Model Strengths and Weaknesses

Strengths

a) AGRMET is a worldwide *near* real-time

Agricultural Meteorological Model
(AGRMET)



FIC E 7

diagnostic model. It is the only one of its kind.

b) AGRMET uses the minimum amount of computer time while producing usable results for all AGRMET customers.

c) Output is much more accurate in data dense areas due to the heavy use of observational data in the model.

d) Many of the constants and arrays in the model can be changed easily by updating the CONTROL file. This allows quick updates to areas when problems are noticed.

Weaknesses

a) AGRMET uses observational data to the fullest extent. Because of this, the model's output becomes less accurate (for most parameters) for points further away from observation sites.

b) When observed data are spread over the first-guess field, variations in elevation are not accounted for. The observed value will be spread (using the Barnes convergent weighted-averaging interpolation technique) to adjacent grid points even if the point is significantly higher or lower.

c) The eighth-mesh resolution is not conducive to analyzing parameters in mountainous *areas.* The spatial variability of the terrain is much greater than the resolution of the model.

d) AGRMET relies heavily on output from other models run at AFGWC like RTNEPH, HIRAS, and SSM/I. Because of this, AGRMET inherits the limitations and weaknesses of these models. For example, RTNEPH has problems determining cloud type information. This will impact AGRMET especially in the calculations of radiation and precipitation.

e) AGRMET does not run for all land points. Some important agricultural areas are missed (e.g., Southeastern Brazil, Western and Eastern Africa).

f) AGRMET assumes a uniform crop cover in the grid-box(25NM x 25NM). Roads, additional vegetation types, or man-made structures are not accounted for. It is possible, and very likely, that there will be a number of different vegetation types growing in the grid box, also the box will probably have roads, structures, and small lakes that would not be accounted for by the model.

g) AGRMET assumes that there are NO urban areas in the world. All points are 100% covered with some sort of vegetation type.

h) AGRMET soil type information is also uniform for the grid box. The variability of soils within the box is not accounted for. This has a major impact on the soil hydrology output.

i) Although AGRMET time-steps through the soil hydrology algorithm in one-hourly increments, input data are only available in three-hourly increments and, in data sparse locations, some of these data are available only in six-hourly increments. (HIRAS produces six-hourly output which becomes the model's first-guess field) In data sparse areas these data would be the same for both three-hourly time steps since observed data would not be spread over the first-guess field. In summary, the temporal resolution of the output is greater than the temporal resolution of the input.

j) AGRMET maximum and minimum temperature for the grid point would be the max/min temperature for a three-hourly period. If the max/min temperature was between three-hourly periods, it would not be reported. This results in a slight warm bias with the minimum temperature, and a slight cool bias with the maximum temperature.

k) In the soil hydrology algorithm, soil moisture is only available from precipitation or snow melt at the gridpoint location. Runoff from other locations, irrigation, or a high water table do not have any effect on the soil moisture. If a gridpoint is at a location with a lot of runoff from other locations where moisture is readily available from the high water table, or there has been no precipitation in the area, the soil moisture will dry out.

AGRMET Precipitation

a) The SSM/I algorithm that produces the rain-rate

EDRs that are used in the AGRMET model cannot produce accurate precipitation estimates.

b) It is difficult to produce precipitation estimates from cloud information as is attempted with AGRMET's cloud indexed Precipitation Coefficients (PCOEFs), especially when there are problems with the cloud information available from the RTNEPH model.

c) The PCOEFs are updated using either the RAINBO estimates of precipitation, or the observed values of precipitation. RAINRO is an estimated precipitation that is calculated using the station's present weather code. There are problems with the RAINRO amount, which varies from region to region, which in turn causes variations in the accuracy of AGRMET from area to area. The use of observed data that *appears* to be much more accurate also has limitations. Missed or poor quality observations (which is common) will effect AGRMET's accuracy.

d) The PRECIP program uses most sources of observed precipitation, but it does not spread the values to adjacent grid points as it does with other outputs such as temperature and wind. The model relies heavily on cloud information to determine precipitation at non-observation grid points.

e) Most of AGRMET's output relies in some way on the accuracy of the precipitation data. For this reason, weaknesses in this area will effect most of the AGRMET model.

See references h and i.

A. Organization responsible: SYSW
B. Equipment: Unisys 1100/91 (Systems 5)
C. Input: Existing AGRMET Database
HIRAS Database
Surface Observations Database
SSM/I Data
Snow/Ice Database
Geography/Terrain Database (XFIX64)
RTNEPH Database (Clouds)
Matthews Vegetation Database
Output: AGRMET Database
- Evapotransgiration
- Soil Moisture

- Precipitation
- Daily Temperatures
- Relative Humidity
- Infrared and solar radiation
- Wind Data

2.3.1.6 Relocatable Window Analysis Model (RWAM)

The Relocatable Window Analysis Model (RWAM), based on the regional optimum interpolation procedure at the National Meteorological Center (NMC), was developed under contract and delivered to AFGWC in 1990. It was utilized in generating the analysis for the RWM from September 1991 until January 1992. At that time, a serious flaw in the software design was discovered which was randomly producing noisy initial fields. If this software design flaw can be repaired, the model initial conditions will be more accurate, and the timelines will allow at least one window to begin running as early as 1.5 hours after synoptic analysis time, which will improve the timeliness of the product for the operational user. Currently, RWM must use the interpolated HIRAS global analysis or the zero-hour GSM forecast for its initial conditions.

2.3.1.7 Atmospheric Slant Path Analysis (ASPAM)

ASPAM is used to generate a "point analysis* (PA) of past environmental conditions for a selected location. It is a description of the atmosphere from the surface to 400,000 feet for any specified location and time. ASPAM usually uses optimum interpolation (OI)rather than relying on a single radiosonde. 01 is a statistical technique that combines several data sources of varying quality to provide the best value for various parameters at various vertical levels.

In addition to vertical profiles, ASPAM can create a PA along a specified slant path, or along a line of sight. A vertical profile touches the surface and is perpendicular to the surface. A slant path also touches the surface but varies in both elevation angle and azimuth angle. A line of sight has the latitude, longitude, and elevation of the end points specified; it need not touch the surface. A vertical profile can be based on the most representative RAOB or on optimum interpolation. The latter is usually recommended. Slant path and line of sight profiles must be based on 01. AFGWC is responsible for PAs with request times less than 24 hours old; USAFETAC processes PA times that are older than 24 hours. Input for the PA computation is taken from 10 databases and several data files. Depending on the communications used, this can be a highly automated process. The 10 databases used are:

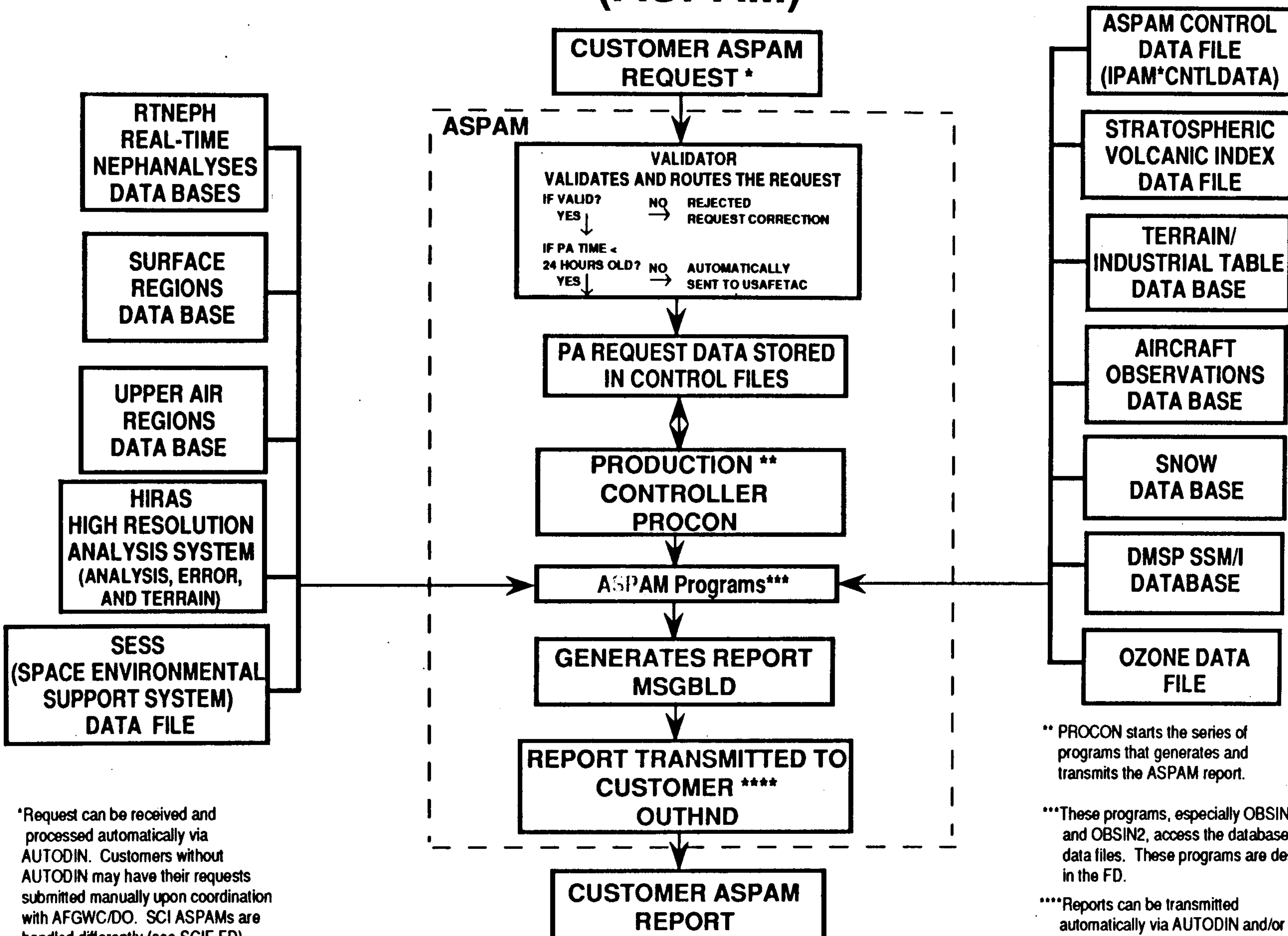
1. RTNEPH Database
2. AFGWC Surface Regions
3. AFGWC Upper-Air Regions (includes RAOB, PIBAL, ROCOB and meteorological satellite based profiles)
4. AFGWC Aircraft Regions
5. High Resolution Analysis System, Analysis
6. High Resolution Analysis System, Error Estimates
7. High Resolution Analysis System, Terrain
8. Terrain/Industrial Table
9. Snow Depth
10. DMSP SSM/I

The IPAM*CNTLDATA file contains data that controls various programs. It includes, in part, sensor errors used by the 01 program. In addition, ASPAM accesses several ASPAM specific data files, e.g. ASPAM*SESS, IPAM*OZONE, IPAM*IVULCN (stratospheric volcanic aerosol), etc.

ASPAMs that are unclassified or collateral classified will be processed by the Weather Information Processing Program (WIPP). Requests for these PAs can be received and processed automatically via AUTODIN. Custoxters without AUTODIN may have their requests submitted manually upon coordination with AFGWC/DO. ASPAM reports, regardless of how they are submitted, can be transmitted automatically via AUTODIN and/or AWN. A single request may have multiple addresses. Customers without AUTODIN or AWN may have their reports transmitted manually, e.g. mail, FAX, etc., upon coordination with AFGWC/DO. For WIPP PAs, requests that are received and transmitted via AUTODIN will be processed completely automatically. ASPAMs that are SCI classified are received and transmitted differently on System 3. Please see the SCIF FD for further information.

ASPAM supports a total of 11 paragraphs. However, three of these paragraphs are mutually exclusive, so that at most 9 paragraphs can appear in a single report. Each report is tailored to customer requirements. The paragraphs are described in the next section. ASPAM is written in FORTRAN. See Figure 8.

ATMOSPHERIC SLANT PATH ANALYSIS MODEL (ASPAM)



*Request can be received and processed automatically via AUTODIN. Customers without AUTODIN may have their requests submitted manually upon coordination with AFGWC/DO. SCI ASPAMs are handled differently (see SCIF FD).

** PROCON starts the series of programs that generates and transmits the ASPAM report.

***These programs, especially OBSIN and OBSIN2, access the databases and data files. These programs are described in the FD.

****Reports can be transmitted automatically via AUTODIN and/or AWN. Multiple addresses per request are permitted. SCI ASPAMs are handled differently (see SC

URE 8

2.3.1.7.1 Content of ASPAM paragraphs

The paragraph letters below correspond to the paragraphs used in ASPAM.

a) Latitude/Longitude or PA Site Identification. The site identification is a six character field called a Point Analysis Identifier. If the sanitize option is on, the PA Site Identification will appear in paragraph (a).

b) Time and date of the PA. If the sanitize option is on, paragraph (b) will be blank.

c) Gridded Cloud Description - This displays a gridded depiction of the low, middle, high, and total cloud cover for the RTNHPH grid points surrounding the PA point. An area extending at least three grid points from the PA site is shown with a nominal grid spacing of 25 NM. The RTNEPH model produces an automated analysis of clouds for both the Northern and Southern Hemispheres. It uses quality controlled data from satellite, surface, and aircraft observations. The RTNEPH produces a snapshot of its analysis every three synoptic hours: 00002, 03002, 06002, etc. ASPAM computes its cloud depiction from the RTNHPH analysis closest to the PA time. For example, an ASPAM profile request for a 16252, 12 May 1988 would use the 1500Z RTNEPH analysis for that day. The data for this function are obtained from the Real-Time Nephanalysis database.

d) Pseudo-Surface Observation - This provides surface visibility, up to four layers of cloud data (bases, togs, and cloud types), total cloud coverage, surface wind data (direction, speed, and gusts), and present weather for the PA point. It is called a pseudo-surface observation because the data are actually for the RTNEPH grid point nearest the PA point and closest to the PA time (at most 17.7 NM and 1.5 hours from the actual PA point and time, respectively). The data for this function are obtained from the RTNEPH and Surface Regions databases. Wind data are based on a surface optimum interpolation, not directly on observations. If RAOBVP was selected and the nearest RAOB was within six NM, then the RAOB surface wind is used.

e) Precipitable Water Profile - This provides the precipitable water amounts for specified layers from the surface to 100,000 feet. Precipitable water is the maximum depth of water that can be precipitated out of a layer. The customer chooses to use either the RAOB(s) nearest the PA point or the 01 based on HIRAS analysis, usually the latter. The thickness of the precipitable water layers varies as follows:

LAYER (FT. AGL)	THICKNESS (FT.)
Surface - a, 000	1,000
8,000 - 20,000	2,000
20,000 - 50,000	5,000
50,000 - 100,000	10,000

Data are computed from the ASPAM vertical profile. See paragraphs f or i for the databases used by RAOB-based or OI-based vertical profiles, respectively.

f) Radiosonde Meteorological Data - This provides the RAOB-based vertical profiles for wind (direction and speed), temperature, absolute humidity, density, and pressure for specified levels from the surface to 400,000 feet (wind and absolute humidity up to only 100,000 feet). ASPAM chooses the most representative RAOB and assumes it is valid at the PA event. This paragraph is mutually exclusive with paragraph h and paragraph i. The vertical resolution of the level varies as follows:

LEVELS (FT. AGL)	VERTICAL RESOLUTION (FT.)
Surface - 8,000	1,000
8,000 - 20,000	2,000
20,000 - 50,000	5,000
50,000 - 100,000	10,000
100,000 - 400,000	20,000

Since most RAOBs do not go above 100,000 feet, the Groves-Mass Spectrometer & Incoherent Scatter 1983 (MSIS/83) model calculates density, temperature, and pressure, but not humidity, above this level. The Groves-MSIS/83 model specifies the state of the upper atmosphere using climatology and recent solar activity. When Rocketsonde Observations (ROCOB) are available, they are used in the ASPAM profile for winds (if winds begin below 100,000 feet), temperature, moisture, density, and pressure. The data for this function are obtained from the Upper-Air Regions, HIRAS Analysis (used to fill missing mandatory levels), and SESS data file.

g) Remarks - This discusses the RAOB, surface information, recent solar activity, data source weight table, quality indices for moisture and temperature, slant path, and moisture consistency, as appropriate for the individual ASPAM request. Remarks are used to enhance the user's overall understanding of the ASPAM output, especially its reliability and consistency. Remarks is a very flexible program and is very responsive to the customer's request. There are only three mandatory data that Remarks will always display: a summary of the nearest RAOB, temperature/moisture quality indices, and the SESS data. When 01 is used to create the profile, the "nearest RAOB" is actually the "most correlated" RAOB. When the profile is created via 01 (including paragraph h), it is recommended that the data source weight table option be selected. The quality indices are not considered reliable. Depending on the options selected by the customer, the data for this program may be obtained from the Upper Air, Surface, HIRAS, SESS, and SSM/I databases. Data are taken from the 01 program or RAOBVP program, and the pseudo-surface observation program (if Surface Observation Table selected).

h) Aerosol Parameters/Vertical Profile Information - This provides information on the boundary layer conditions, seasonal data, visibility, ozone, and effects of volcanic activity. This paragraph is designed to provide information for the Phillips Lab Atmospheric Low Resolution Transmittance Model (LOWTRAN). The vertical profile section provides pressure, temperature, and absolute humidity. It also provides one sigma alternate vertical profiles for temperature and absolute humidity. The vertical profile data are calculated via 01. This paragraph is mutually exclusive with paragraph f and paragraph i. The vertical resolution of the vertical profiles varies as shown in the table following this paragraph, the user may specify up to 11 additional pressure levels to be calculated and disglayed. The aerosol parameters are taken from the Terrain/Industrial Table, HIRAS analysis, and the Stratospheric Volcanic Aerosol databases. Data are also taken from the Surface, Upper Air, and Ozone databases and the OIDRVR and PARAD programs.

LEVELS (KM. MSL)	VERTICAL RESOLUTION (KM.)
Surface - 2.5	.25
2.5 - 5.0	.50
5.0 - 10.0	1.00
10.0 - 30.0	2.50
30.0 - 50.0	5.00
50.0 - 100.0	25.00

i) Optimum Interpolation Meteorological Data Profile -This provides the 01 based vertical profiles for wind (direction and speed), temperature, pressure, density, and absolute humidity (below 100,000 feet). This paragraph is identical to paragraph f, except that the profile is derived by the 01 process, rather than the RAOB-based process. As in paragraph f, RGCOB data will also be included in the profile. Below 100,000 feet, acceptable RGCOB data will be treated as observational data. Above 100,000 feet, acceptable RGCOB data will be splined into the Groves-MSIS/83 profile (wind data must have begun below 100,000 feet). This paragraph is mutually exclusive with RAOB-based paragraph f and paragraph h. As with the precipitable water profile, the customer must choose between a RAOB or OI-based point analysis, usually selecting the 01-based. The customer can also choose to have this output displayed in paragraph f. The data for this function are obtained from the three HIRAS databases: analysis (temperatures, winds, humidity, and D-values); error estimates (same data as analysis); and terrain (surface heights). Data are also obtained from the Surface Regions, Upper-Air Regions, Aircraft Observations, Terrain/Geography, and SESS databases.

j) 24-Hour Surface Weather History - This provides a 24-hour weather history for the PA point. The first line is valid at the PA time. The subsequent eight lines are valid at three-hour intervals, starting with the synoptic time (OOOOZ, 03002, 06002, etc.) closest to the PA time. For example, an ASPAM profile request for 10352, 21 Aug 1987 would start with the 12002 RTNEPH analysis for that day. Each of the nine surface observations are coded to include present weather, precipitation type, up to four layers of clouds (base, coverage, and thickness), total cloud coverage, visibility, obstruction to visibility, pressure, temperature, dew point, and wind data (direction, speed, expected speed variation). The maximum and minimum temperature during the 24-hour period and snow depth are also reported. The data for this function are obtained from the RTNEPH, HIRAS, and Snow/Ice databases. Data are also taken from the Pseudo-Surface Observation program and the selected vertical profile (VP) program (RAOBVP or OIVP).

k) Refractive Index - This paragraph provides profiles 'of wind, temperature, relative humidity, and of radio and optical indices of refraction. The profiles also provide the vertical change in the radio index of refraction, and lists the refractive condition for the layer. These profiles are calculated from previously constructed vertical profiles. Please see the appropriate vertical profile for the databases that influence this paragraph. Output data is for heights up to 100,000 feet, and at intervals of 500 to 2500 feet. Unlike the other ASPAM profiles, the height and interval are determined by the user.

2.3.1.7.2 Databases Used by ASPAM

The following AFGWC databases are used by ASPAM

1.	AFGWC*DATMANXTPRB	Upper-Air Observations
2.	AFGWC*DATMANXTSFC	Surface Observations
3.	AFGWC*DATMA.NXTAIR	Aircraft Observations
4.	AFGWC*DATMANXSNDEP	Daily Snow Depth (Model output)
5.	AFGWC*DATMANXFIX64	Geography Data (fixed fields, terrain and aerosol type)
6.	AFGWC* DATMANXHRASA	HIRAS Analysis (Model output)
7.	AFGWC*DATMANXHERRA	HIRAS Error (Model output)
8.	AFGWC*DATMANXHIRST	HIRAS Terrain (Fixed Fields)
9.	AFGWC*DATMANXRTNOR	RTNEPH; Northern Hemisphere
	AFGWC*DATMANXRTSOU	RTNEPH; Southern Hemisphere (both model output)
10.	DMSP SSM/I	DMSP SSM/I parameters

In addition, ASPAM uses several ASPAM specific data files, e.g. ASPAM*SESS, IPAM*OZONE, IPAM*IVULCN (Stratospheric Volcanic Aerosol), etc.

ASPAM is a system of programs. Some programs will be used by every PA request; some programs will not (contingent on the ASPAM options/paragraphs requested). In the following subparagraphs, "Accesses" means the program reads the indicated databases or data files directly. "Also used" means the program uses the indicated data indirectly (i.e., the data is read by another program and then passed to this program), or uses the output from other ASPAM programs which in turn have used the data.

a) IPAM*OBSIN and IPAM*OBSIN2. These two programs are used to load most of the databases needed by OIDRVR (all PA requests, except RAOBVP). OBSIN reads the observational and fixed-field databases. 0BSIN2 reads the HIRAS databases. Except for RAOBVP requests, these programs do most of the database reading for ASPAM. Subsequent ASPAM programs use these data to build the various paragraphs of the ASPAM report.

Accesses: AFGWC*DATMANXTPRB
AFGWC*DATMANXTSFC
AFGWC*DATMANXTAIR
AFGWC*DATMANXFIX64
AFGWC* DATMANXHRASA
AFGWC*DATMANXHERRA
AFGWC*DATMANXHIRST

Also Uses: None

b) IPAM*OIDRVR*. This is used by all PA requests, except RAOBVP; See Paragraph i. The Aerosol/Vertical Profile, paragraph h, uses the output from this program. 01 is used to create the final ASPAM profile based on all the databases read by IPAM*OBSIN and IPAM*OBSIN2.

Accesses : ASPAM*SESS (used by the GROVES-MSIS/83 model within IPAM*OIDRVR to extend the profile above 100,000 feet)

Also Uses: All accessed by IPAM*OBSIN and IPAM*OBSIN2

• The function of IPAM*OIDRVR will be split into two programs in the near future: IPAM*OIDRVR and IPAM*OIFIN. OIDRVR will access all the above databases and data files, except SESS. OIFIN will access the SESS data. The GROVES-MSIS/83 model may also be separated eventually out of IPAM*OIFIN.

c) IPAM*CLOUDS. This is used only by PAs that request a gridded cloud depiction; See ASPAM paragraph 'c'.

Accesses: AFGWC*DATMANXRTNOR
AFGWC*DATMANXRTSOU

Also Uses: None

d) IPAM*PARAD. This is used only by PAs that request a pseudo-surface observation; See ASPAM paragraph 'd'.

Accesses: AFGWC*DATMANXRTNOR
AFGWC*DATMANXRTSOU
AFGWC*DATMANXTSFC

Also Uses: IPAM*OIDRVR output (for wind data) IPAM*RAOBVP output (if RAOBVP selected and nearest RAOB within 6 NM)

e) IPAM*PRECIP. This is used only by PAs that request a precipitable water table; ASPAM paragraph 'E'. This program uses the vertical profile created by other ASPAM programs. The vertical profile can be created as either a RAOB based vertical profile (RAOBVP) or an OIVP. Each of these two methods may access some of the same databases, but will use them differently.

Accesses: None

Also Uses: IPAM*OIDRVR output, if OIVP is used, or IPAM*RAOBVP output, if RAOBVP is used

f) IPAM*RAOBVP. This is used only by PAs that request a RAOB based vertical profile; See ASPAM paragraph 'f'.

Accesses : AFGWC*DATMANXTPRB
AFGWC*DATMANXTSFC
AFGWC*DATMANXHRASA (used to fill missing RAOB mandatory levels)
ASPAM*SESS (used by GROVES/MSIS model within IPAM*RAOBVP to extend the profile above 100,000 feet).

Also Uses: None

* The function of IPAM*RAOBVP will be split into two programs in the near future: IPAM*RAOBVP and IPAM*RAOBFN. RAOBVP will access all the above data and data files, except SESS. RAOBFN will access the SESS data. The Groves-MSIS/83 model may also be eventually separated out of

RAOBFN.

g) IPAM*REMARKS. Except for the PA event data in paragraphs a and b, this is the only paragraph displayed by every PA request. Output is displayed in ASPAM paragraph 'G'. This program directly accesses only SESS data. However, it uses many databases previously accessed by other ASPAM programs. Which databases are used depends on which type of vertical profile (e.g., RAOBVP, OIVP, or Paragraph h), was selected and on which options were selected.

Accesses : ASPAM*SESS

Also Uses: IPAM*OIDRVR output (if data source weight table option selected)
IPAM*RAOBVP output (if RAOBVP used)
IPAM*PARAD output (if surface observation table option selected)

h) IPAM*PARAH. This is used only by PAs that request the aerosol option; See ASPAM paragraph 'h'.

Accesses: AFGWC*DATMANXHRASA (for time since land)
AFGWC*DATMANXFIX64 (for surface type)
IPAM* IVULCN

Also Uses: IPAM*OIDRVR
IPAM*PARAD

i) IPAM*SFCWX. This is used only by PAs that request the 24-Hour surface weather history; See ASPAM paragraph 'j'.

1) The data for the PA event time are taken from previous ASPAM programs. IPAM*PARAD provides visibility, present weather/obstruction to visibility, and clouds. The surface data from the vertical profile, either IPAM*OIDRVR (including IPAM*PARAH) or IPAM*RAOBVP, provides pressure, dew point, and winds.

2) The data for the subsequent eight three-hour times are taken directly from the databases. AFGWC*DATMANXRTNOR and/or AFGWC*DATMANXRTSOU provide visibility, present weather/obstruction to visibility, and clouds. AFGWC*DATMANXHRASA provides temperature, dew point, pressure, and winds.

3) AFGWC*DATMANXSNDEP provides snow depth information

for all of this program.

Accesses: AFGWC*DATMANXSNDEP
AFGWC*DATMANXRTNOR
AFGWC*DATMANXRTSOU
AFGWC*DATMANXHRASA

Also Uses: IPAM*PARAD output

j) None of the numerous other programs within the ASPAM system access or use the AFGWC databases or data files.

k) Refractive Index Profile. The refractive index profile is produced as part of IPAM*OIDRVR or IPAM*RAOBVP, depending on how the profile is created. This paragraph doesn't have its own separate program. Please see the descriptions of OIDRVR or RAOBVP, as appropriate, for the databases that influence the refractive index profile.

A. Organization responsible: SYSM
B. Equipment: Unisys 1100/91 (Systems 5)
C. Input: RTNEPH Cloud Database
Surface Regions Database
Upper-air Database
HIRAS Database (Analysis, Error, and Terrain)
SESS Data
Stratospheric Volcanic Index Database
Terrain/Industrial Table
Aircraft Observations Data
Stratospheric Volcanic Aerosol
Snow Depth Database
DMSP SSM/I database
Output: Point Analysis Paragraphs

See reference p for a general reference. This reference has attachments that discuss Optimum Interpolation, RAOB and 01 vertical profiles, ASPAM slant path capabilities, the Groves-MSIS/83 model, alternate temperature and moisture profiles, and the refractive index profile along with numerous other topics.

2.3.2 Forecast Models

2.3.2.1 AFGWC Five-Layer Model (5LAYER)

The 5LAYER model is an automated, synoptic scale, cloud forecasting program. It runs on System 5 and its primary purpose is to produce cloud forecasts over two hemispheric domains for planning weather purposes. Note that the tropical regions are analyzed by the TRONEW model. Temperatures and moisture are forecast and combined to produce other forecast parameters such as icing and precipitation type. SLAYER produces a forecast for layered cloud amounts, total cloud amount, dew point depressions, temperatures, and present weather. In addition, static stability, cloud types, icing, and precipitation are forecast for the Northern Hemisphere only. See Figure 9.

The 5LAYER model forecasts clouds and temperatures at the gradient, 850, 700, 500, and 300mb levels in three-hour increments out to 48 hours in the Northern Hemisphere and 24 hours in the Southern Hemisphere at a spatial resolution of 100 NM (half-mesh). The choice of the three-hour time step is based on convenience rather than necessity. Winds and vertical velocities are obtained from the GSM (40-wave and 12-level), and are available in three-hour increments; therefore., wind trajectories are computed to represent parcel movement over that same time increment. Cloud forecasts represent average cloud conditions over a large volume. This volume is referred to as a parcel. Cloud data is obtained from the RTNEPH database and moisture and temperature data are obtained from the HIRAS database. The first 24 hours of 5LAYER data plus SLAYER forecast data are stored in the SAVDOX database and is used on SDHS and by the Selective Display Model.

Temperature forecasts in combination with cloud forecasts can produce additional meteorological elements. Two important elements are precipitation and icing. The SLAYER model uses several methods to produce forecasts of precipitation amount, precipitation type, and icing. Dew point depressions, static stability, and cloud types are forecast to determine these elements.

Generally, SLAYER uses a quasi-Lagrangian advection scheme to determine the advected elements. A pure Lagrangian scheme follows a parcel throughout the forecast period. SLAYER follows the parcel in three-hour increments until the end of the forecast period. A characteristic of this scheme is that the wind trajectory remains fixed at one end while the other end specifies the source of the parcel. This upstream trajectory requires a gridded analysis to provide values of the element at the source point. The value of the element is determined by interpolation of the source point and

Five-Layer Model
(5LAYER)

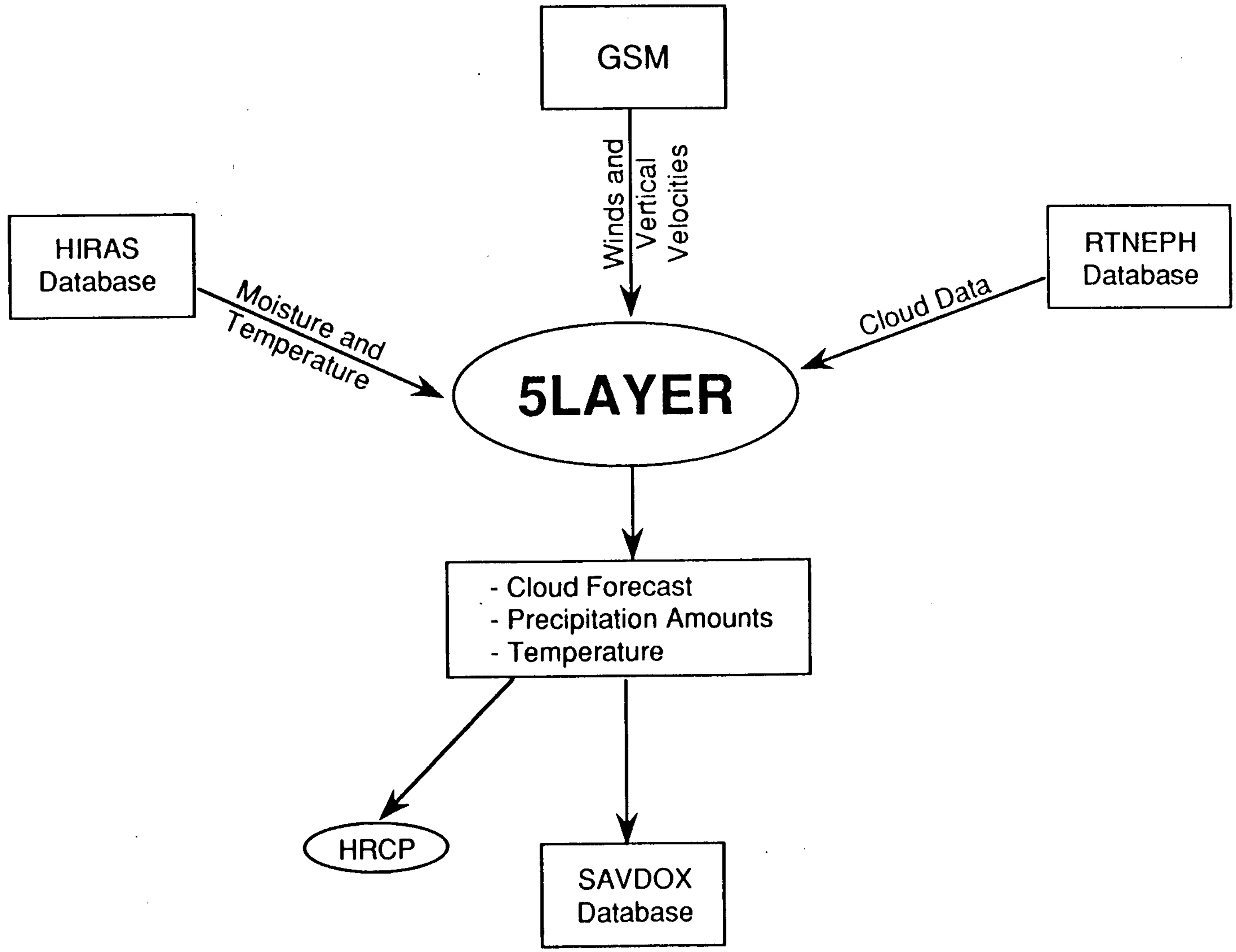


FIGURE 9

is modified as it traverses the trajectory path. Since all trajectories terminate at a grid point, a gridded forecast field results. This procedure is repeated with each forecast field serving as the initial field for subsequent forecast increments until the desired forecast length is reached.

5LAYER runs every three hours per hemisphere, eight times a day, 1.5 hours after data time in the Northern Hemisphere and 2.5 hours after data time in the Southern Hemisphere. SLAYER runs on the Unisys 1100/91 (System 5) in about five minutes and uses about 256K of memory. It is written in *FORTRAN* 4, but has some modules in FORTRAN *77.*

MODEL STRENGTHS AND WEAKNESSES

Strengths:

a) SLAYER performs best at 700 and 500mb. The analyses on which 5LAYER depends provides the most valid and complete data fields at these levels. SLAYER under-forecasts clouds at the gradient and 850mb levels mostly due to terrain effects and because RTNEPH analys tend to be under analyzed.

b) SLAYER executes fast and is reasonably accurate, especially'for the first 24 hours.

Weaknesses:

a) In areas where horizontal winds are weak, clouds may not move due to rounding errors from interpolation techniques. The trajectory prediction from GSM wind data tends to be the most influential *factor* in forecasts made for the 21 to 48 hour time frame.

b) Some errors are introduced due to weaknesses in the parameterization techniques (entrainment, diurnal effects, and precipitation)._

c) Compaction of cloud amount from RTNEPH eighth-mesh to half-mesh for use by SLAYER tends to smooth cloud boundaries and clouds below the gradient level are placed at the gradient level during the initialization.

For additional information on this model, see references e and f.

A. Organization responsible: SYSM
B. Equipment: Unisys 1100191 (Systems 5)
C. Input: HIRAS Database (moisture and temperatures)
GSM Database (winds and vertical velocities)
RTNEPH Database (cloud data)
output: SLAYER Database
- Cloud Forecasts
- Precipitation Amounts
- Temperatures
SAVDOX Database
(SLAYER data also used by SDHS and the Selective Display Model (SDM))

2.3.2.2 High Resolution Cloud Prognosis (HRCP)

The HRCP is used to make a short range, high resolution cloud forecast. HRCP is the final step in the sprint cycle (except for the final bogus). The model forecasts total cloud cover and layered cloud cover for 15 levels on an eighth-mesh grid for a quarter-orbit at a time. This eighth-mesh grid coincides with the one used in the RTNEPH. In addition, a percent total cloudiness is forecast for each eighth-mesh point. Forecasts are made in three-hour time steps to a maximum of nine hours.

The HRCP is capable of making an advection forecast for that portion of the eighth-mesh grid within the AFGWC octagon. HRCP uses either a persistence or diurnal persistence technique for areas outside the octagon. The octagon is basically just a subset of the whole and half-mesh grids with the corners cut off. See reference e, pages 2-3 for a description. However, the advection module of the HRCP only forecasts for a single window of this area in any one computer run. This window can be located anywhere in the octagon; however, the window must coincide with one or more of the boxes of the eighth-mesh grid.

The HRCP can be initiated for any starting hour, and it accesses the SLAYER database to use the wind trajectories already stored there. It has the option to make any length forecast out to nine hours in three-hour increments.

The HRCP is initialized directly from the RTNEPH converted to look like the old 3DNEPH database (primarily 15 layers of cloud information). No modification of the cloud amounts is made by HRCP. To produce an eighth-mesh cloudiness forecast, HRCP uses wind trajectory and Condensation Pressure Spread (CPS) information available in the SLAYER, cloud data from the RTNEPH, and dew point data from HIRAS. These are interpolated to eighth-mesh and the cloud data is converted to CPS. HRCP chooses the most timely CPS from SLAYER and RTNEPH and then advects this with a quasi-Lagrangian technique, the same principle as used in the SLAYER model. See Figure 10.

HRCP runs on System 3 every sprint quarter-orbit, or approximately 30 to 35 times per day. The cloud forecasts from HRCP are stored in the SAVDOX database.

MODEL STRENGTHS AND WEAKNESSES

Strengths:

a) The model works on six vertical layers. However, a trajectory can be mapped to several layers, thus simulating the mean wind of a cloud layer.

b) The HRCP is a pure advection scheme which works well for synoptic systems for the first nine hours.

c) The HRCP is slightly pessimistic in the amount of cloud cover forecasted.

d) The HRCP runs very fast; two to three minutes of wall-clock time on a Unisys 1100/91. It is written in FORTRAN.

Weaknesses;

Cumulus forecasts are not handled at all in this model. HRCP uses a cumulus value from the CUFCST model if the CUFCST value is higher for selected months and areas. During April through September for the area O-60 degrees east, CUFCST runs twice a day on System 3 at 02502 (after the upper-air data comes in) and again three hours later. It runs prior to HRCP. Also, HRCP doesn't handle stratus formation and dissipation.

For additional information, see Appendix B and reference e.

A. Organization responsible: SYSM

High Resolution Cloud Prognosis Model
(HRCP)

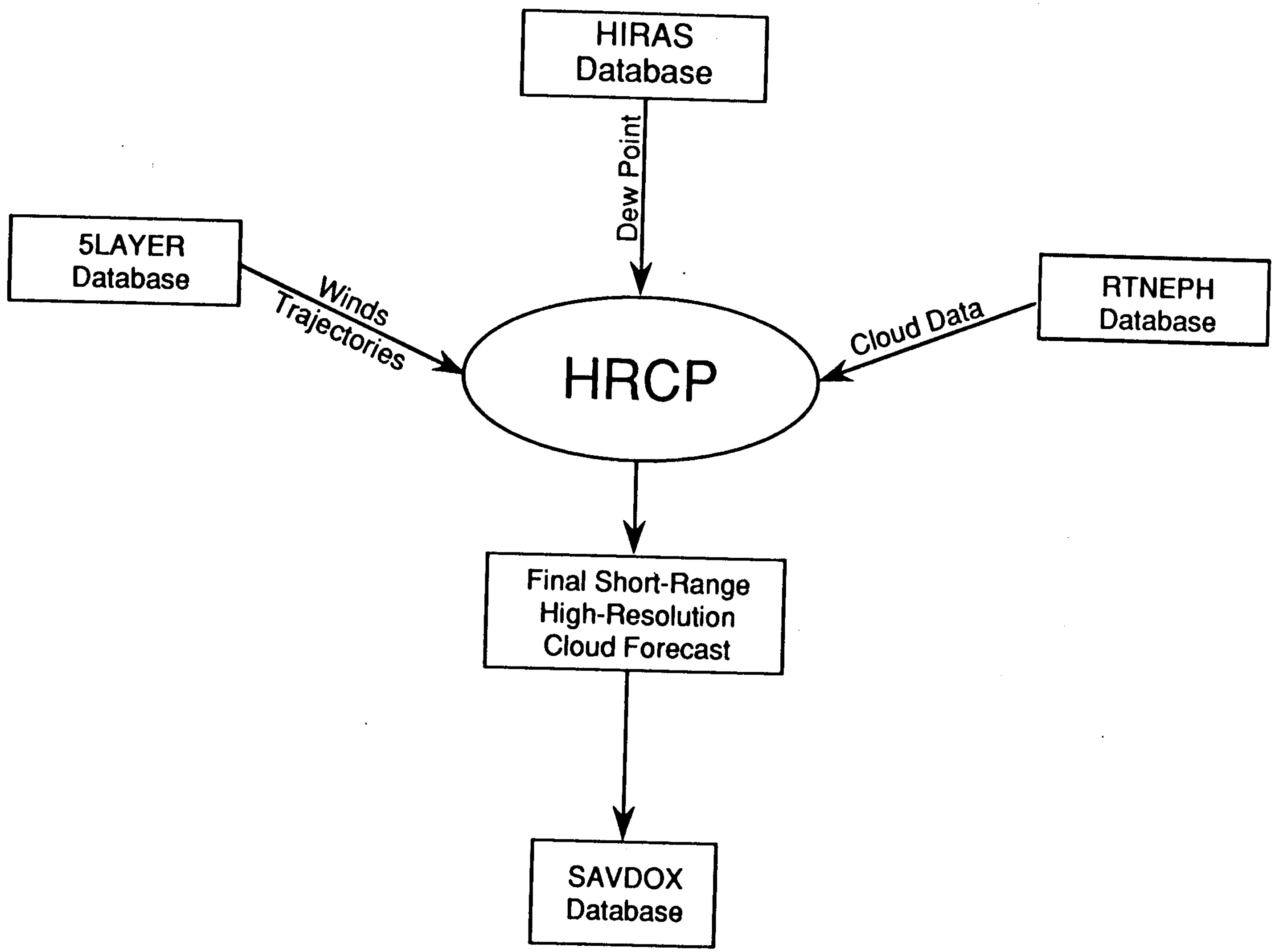


FIGURE 10

B. Equipment: Unisys 1100/91 (Systems 5)

C. Input: 5LAYER Database (winds, trajectories)
HIRAS Database (dew point)
RTNEPH Cloud Data

Output: SAVDOX Database (short range cloud forecast data)

2.3.2.3 Tropical Cloud Forecast Model (TRONEW)

The Tropical Cloud Forecasting Model is the primary cloud forecasting tool for the tropical regions of the earth. The tropical region is from 25° north to 25° south. The model produces forecasts for three layers (low, middle, and high) on the AFGWC Northern Hemisphere and Southern Hemisphere half-mesh grid (100NM resolution). The model uses a 24-hour diurnal persistence technique. Forecasts are made every three hours in three-hour increments out to 21 hours.

TRONEW uses the premise that in the tropics there are diurnal fluctuations of cloudiness and, therefore, clouds that were observed yesterday at a certain time of day will again be observed today at that same time. This premise works well except in the vicinity of moving tropical disturbances (e.g., typhoons, and easterly waves).

To initialize the half-mesh grid, a nine-point weighted averag. of the eighth-mesh RTNEPH grid is used. This compacted analysis is then saved, so that if a six-hour forecast is needed from a 23/0600Z base time, TRONEW will use the 22/1200Z analysis as the forecast. The TRONEW model runs on System 5 (one hemisphere at a time, north and south, after SLAYER is finished). The output is also copied to System 3 and stored in the SAVDOX database and is used on SDHS and the Selective Display Model.

Note that the southern RTNEPH has much less conventional data available (surface and upper-air). This results in a slightly degraded analysis for the Southern Hemisphere. The fact that much of the land area in the Southern Hemisphere is located in the tropical region causes some additional problems. The Intertropical Convergence Zone (ITZ) and other related phenomena are typical tropical anomalies. The combination of these problems consequently results in a somewhat degraded automated forecast. See Figure 11. TRONEW runs on System 5 (Unisys 1100/91) every three hours per hemisphere and takes about one minute to run. It uses about 56K of memory and is written in FORTRAN 77. For additional information, see reference e.

Tropical Cloud Forecast Model
(TRONEW)

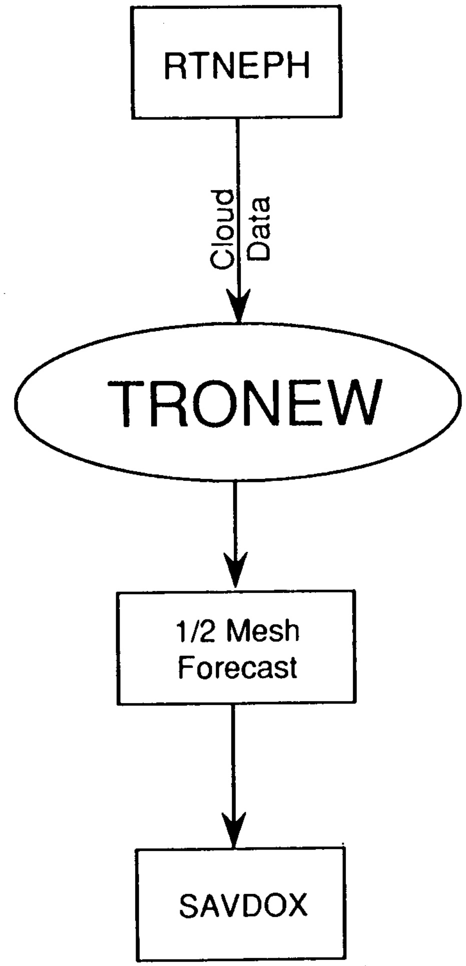


FIGURE 11

Model Strengths and Weaknesseg

Strengths

- The model is better than persistence

Weaknesses

- Uses an assumption of diurnal persistence, but RTNEPH does not provide time continuous data. In particular, the only reliable update times are 0530, 0900, 1430, and 2100 local time. Therefore, the diurnal convective cycle is not captured

- No advection of easterly waves or other tropical disturbances

- Three to six hour persistence usually is better than three to six hour diurnal persistence

A. Organization responsible: SYSM
B. Equipment: Unisys 1100/91 (Systems 5)
C. Input: RTNEPH Cloud Data
Output: SAVDOX Database (short range cloud forecast data)
(TRONEW cloud data also used by SDHS and the Selective Display Model (SDM))

2.3.2.4 Relocatable Window Model (RWM)

Model Characteristics

The RWM was purchased from the NMC in 1982; it's main function at the NMC was to track hurricanes in a non-operational environment. It is a regional-scale primitive equation model that uses a quasi-Lagrangian advection scheme to predict u and v wind components, potential temperature, surface pressure, and specific humidity. It employs a single, unstaggered horizontal grid and uses the sigma (terrain-following) vertical coordinate system.

The current RWM uses a basic boundary-layer physics package in which bulk transfer of sensible and latent heat is allowed over the ocean when the sea surface temperature is greater than the air temperature and surface friction is modeled with a terrain-dependent drag coefficient. Large scale and convective precipitation modules are included in the model, and evaporation of falling precipitation is allowed to occur. The cumulus convection scheme is a Kuo-type which allows deep, moist convection to occur when a saturated parcel originating in the lower model atmosphere can rise through at least two adjacent vertical layers above the Lifting Condensation Level. RWM does not account for land surface processes, diagnosed cloud fraction, and solar/terrestrial radiative processes.

Model Inputs

The current RWM analysis (RWAM) uses an interpolation of the HIRAS global analysis from mandatory pressure levels to the RWM horizontal and vertical grid structure. RWM uses input from RWAM (temperature, winds, moisture, and pressure) and the GSM forecast database (boundary layer data, winds, pressure, and temperature). The -sea-surface temperature analysis is received every 12 hours *from* the Navy's Fleet Numerical Oceanography Center (FNOC) and is interpolated from the 2.5° (150NM) analysis field to a 25, 50, or 100NM grid spacing as required. RWM terrain is 'derived from interpolation of the Navy's ten-minute terrain elevation database. RWM does not account for land surface characteristics such as soil moisture, albedo, or snow/ice cover; it does indirectly account for terrain roughness through use of a surface drag coefficient.

The current RWM uses lateral boundary conditions provided every three hours from *GSM.* The model is initialized with a vertical-modes initialization scheme adapted from NMC. This scheme attempts to remove high frequency modes (e.g., gravity waves) that can cause "spin up" problems during the first several hours of the forecast. A Perkey-Kreitzburg tendency blending scheme was used to transition the GSM forcing it into the RWM's boundary zone (the outer five grid rows/columns); however, this scheme recently was replaced by a relaxation technique similar to that used in the Penn State/National Center for Atmospheric Research (NCAR) mesoscale model. The relaxation scheme contains a nudging term which acts to "force" the values of the RWM variables towards the GSM solution in the boundary zone, and has a nudging coefficient that determines how strongly the forcing is to take place.

To help alleviate terrain incompatibilities between the RWM and GSM over regions of steep topography, a scheme that blends the two terrain fields in the boundary zone also was implemented recently.

RWM has exceeded the GSM in terms of forecast quality. Monthly statistics of the differences between RWM and GSM are being produce, and analyzed. Also, RWM forecast fields are being compared to NMC daily weather maps which are considered to be a very reliable ground truth. See Figure 12.

The Swedish Limited Area Model (SLAM) Planetary Boundary Layer physics package is currently coded in the RWM but has not been thoroughly tested. Extensive sensitivity tests will be conducted over the next couple of years. The SLAM package was developed originally at the European Center for Medium Range Weather *Forecasts (ECMWF).* It consists of three main modules:

a) Surface layer/mixed layer. The surface layer fluxes are based on the Monin-Obukhov similarity theory. The form of the flux equations for momentum, sensible heat, and moisture are dependent upon the stability of the surface layer. The surface layer fluxes require information about the land surface, such as snow depth and soil moisture. The goal is to be able to initialize these two land surface parameters with real-time values from AFGWC's Snow/Ice Analysis Model and the AGRMET model, respectively. The fluxes above the surface layer are handled using mixing length theory. The vertical mixing coefficients depend on thermal stability and wind shear so that the fluxes are consistent with the surface fluxes.

b) Radiation package (including cloud fraction diagnosis). The SLAM radiation scheme is only used to predict the surface (ground) temperature which then determines the state of the PBL. Radiation processes in the free atmosphere (such as long-wave cooling) are not considered due to the relatively short time scale of the model forecast (36 hours; only 1.5 diurnal cycles).

The long-wave radiational component for the surface budget includes both upward and downward components, and requires knowledge of surface infrared emissivity. Currently, this surface parameter would have to be specified as a constant based on characterization of the land surface (some combination of soil type, natural vegetation cover, and land use). The long-wave radiation scheme also needs information about cloud fraction. The current SLAM package diagnoses cloud fraction based on the maximum relative humidity found in each of four vertical groupings of model sigma layers, representing stratus/fog, low, middle, and high cloud types. The amounts are then added together and the total cloud fraction is used to modify the flux of downward propagating long-wave radiation.

Relocatable Window Model
(RWM)

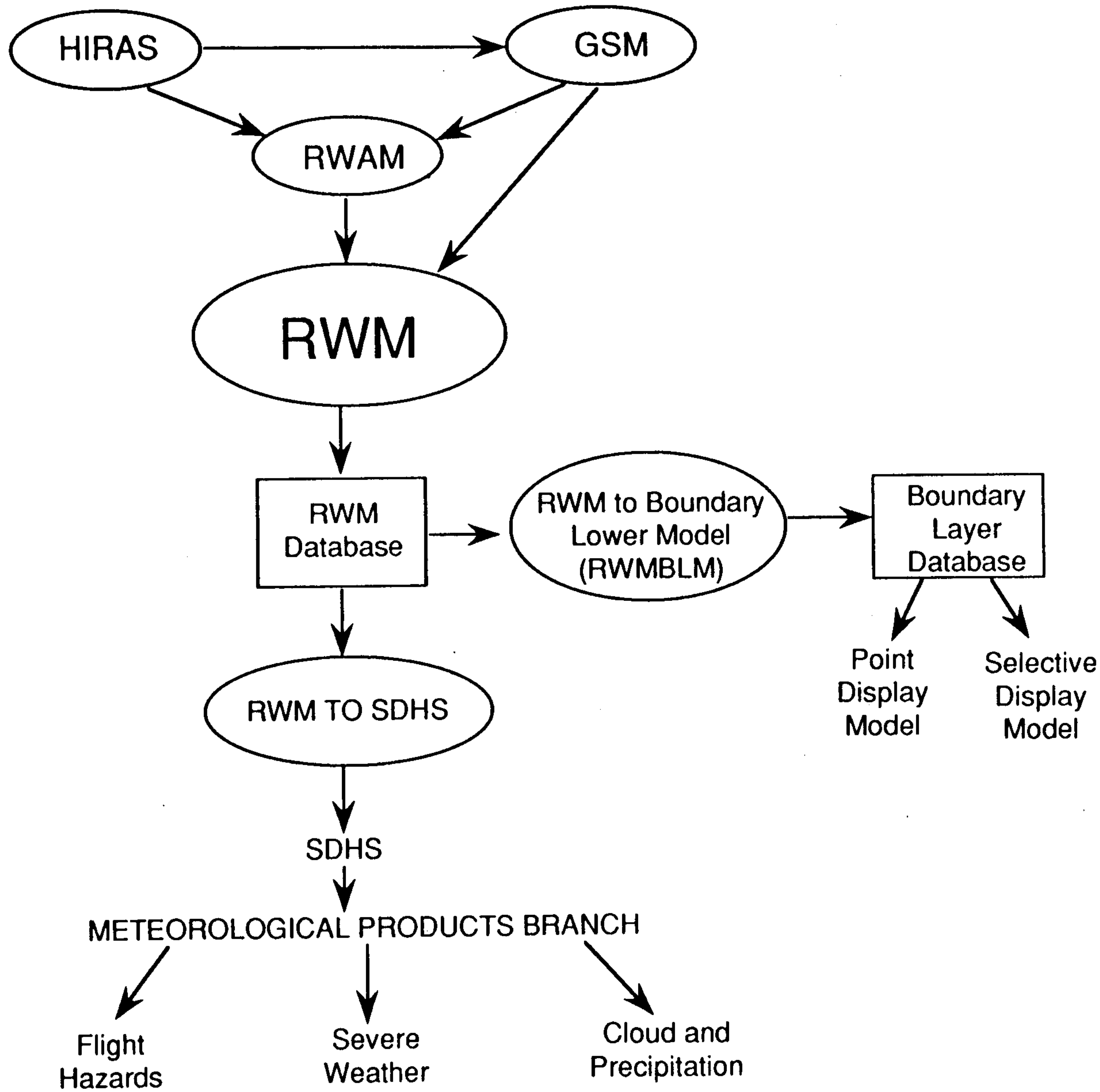


FIGURE 12

The short-wave radiation package accounts for absorption by water vapor and scattering by stratus/fog, low, middle, and high cloud types. The short-wave radiative flux absorbed at the surface requires knowledge of the surface albedo; this information is available from either the AGRMET or SFCTMP models. Although the values vary horizontally, they are based on climatology and only change quarterly.

c) Predictive equations for surface temperature and ground moisture. The SLAM package includes a predictive equation for surface temperature over land. This equation, which is essentially a surface energy budget, requires knowledge of soil heat capacity and thermal conductivity. These variables are available from the AGRMET model, although they are held temporally constant and are simply a function of soil type. A deep soil temperature is also required for the soil heat conduction term of the surface energy budget; soil temperature at a two meter depth is available from the AGRMET model. SLAM also accounts for melting snow. The ground moisture predictive equation is a budget type which accounts for evaporation, moisture diffusion into the soil (regulated by the precipitation and presence/absence of snow), snow melt, and runoff (when the soil moisture exceeds a critical value).

RWM Configuration at AFGWC

The current RWM configuration consists of three fixed windows (CONUS, Europe, and Asia) and one movable contingency window which runs twice a day (0000Z, 1200Z cycles). All four windows use 17 vertical levels (16 layers). The three fixed windows use a 92.6km horizontal grid spacing which is equivalent to a 50NM spatial grid point separation (quarter-mesh); the CONUS window domain size is 61 x 61 quarter-mesh grid boxes; the European domain size is 75 x 65; and the Asian domain size is 73 x 69. The contingency window size is 61 x 61, but the horizontal grid spacing can be user-specified; most often they are either 185.1km, 92.6km, or 46.3km (100NM, 50NM, or 25NM).

The manual procedure to change or set the windows is an interactive process. It takes approximately five to ten minutes on System A and asks the analyst a series of questions (e.g., grid point spacing, the window's center point latitude and longitude, projection type, and physics). The grid must match the one used by RWM on the Cray. It takes approximately 15 minutes to relocate the model based on the parameters set in the interactive process. It is difficult to change one of the fixed windows because the databases are locked to specific geographic regions. The database structure was developed around 1960 and works well; however, this structure was "developed locally" and would be extremely difficult to change_.

Model Outputs

RWM computes winds, moisture, temperatures, and pressure data and saves this data for use by SDHS DOM/DOF personnel. The three fixed window products are available every three hours, through 36 hours, at 12 mandatory pressure levels, the 16 sigma layers, and the surface. Additional hourly output is available at eight boundary layer levels ranging from three meters to 1600 meters above the local surface. The contingency window output is available every three hours at the same mandatory pressure levels and sigma layers, plus the surface, through 36 hours. No boundary layer levels are available from this contingency window. Tailored output including diagnostic/derived variables (e.g., vorticity, dew point, etc.) will be available on AFGWC's Satellite Data Handling System by the end of 1992.

RWM Timelines

The four windows begin execution approximately 5.5 hours after synoptic analysis time. Data starts coming into AFGWC at OOOOZ and 1200Z and takes about three hours. Then the HIRAS and GSM models run for about two hours. HIRAS must be finished and GSM must be past the 48-hour forecast simulation before RWM can start. The windows are run in the following order: CONUS, Europe, Asia, and contingency. The CPU time (on a single-processor Cray X-MP) for a 36-hour forecast varies from 400 seconds for the CONUS and contingency windows, to 550 seconds for the Asian window. The final window forecast finishes approximately nine hours after synoptic analysis time.

Program Descriptions

1. RWSSMT Program - This program reads in Navy sea surface temperatures and averages 6-hourly 1000mb HIRAS temperatures over the last 24 hours. It runs 45 minutes after cycle time (0045Z or 12452). It also reconfigures the time sequence (in Julian hours) on the Cray so it will be compatible with running a specific window with the most recent cycle.

2. WNDREQ Program - This is an interactive program that allows an SYSM programmer to set the grid to certain specifications. When

this is done, the programmer submits XXRWCT for processing.

3. XXRWCT Program - This program sets the grid on the front-end (Unisys, System A) using the specifications from WNDREQ. When this is complete, XXRWCT submits CXXRWCT for processing.

4. CXXRWCT Program - This program sets up the same WNDREQ specified System A grid structure on the Cray. When this Cray grid is configured, CXXRWCT submits XXRWAM for processing.

5. XXRWAM Program - This program starts interpolating the HIRAS grid to RWM on Unisys System A; these interpolated fields serve as the analysis for the RWM. When complete, XXRWAM submits CXXRWAM for processing.

6. CXXRWAM Program - This program sets up the same interpolated analysis fields on the Cray. When complete, CXXRWAM starts RWFM/XXX.

7. RWFM/XXX Runstream - This runstream activates the initialization, forecast, and post processing modules in the RWM. The forecast module actually performs the forecast calculations at each grid point for each of the 16 layers within the model (XXX indicates the window - USA, EUR, ASA, CN1, CN2, CN3, and CN4). When this runstream completes it's execution on the Cray, two things happen:

a. The forecast fields are transferred from the Cray to System A via a Station-to-Station Transfer (SST). The job STORXX (where XX = US, EU, AS, C1-C4) stores the proper fields into the DATMAN database on System A (in the proper fields).

b. RWSTAT is run (initialized by STORXX) which generates quantitative statistical comparisons between. observations and RWM forecasts. On the 28th of each month, the statistics are printed.

RWM is written in *FORTRAN 77* and runs on the Unisys 1100/72 (System A) and the Cray.

MODEL STRENGTHS AND WEAKNESSES

<u>Strengths:</u>

a) The RWM is readily relocatable to any geographical region on Earth.

b) The RWM may use three types of pap projections (Polar Stereographic, Lambert conformal, and Mercator). These projections allow great latitudinal flexibility.

c) A maximum of four RWM windows may be executed every 12 'hours; these windows consist of three fixed windows and one contingency window. The three fixed windows use a grid spacing of 50NM and are permanently anchored over the USA, Europe, and Asia, respectively. However, the contingency window may be run with a variable grid spacing, usually 25, 50, or 100NM.

d) The RWM may utilize either a coarse 2.5° terrain or detailed Navy ten-minute terrain. The ten-minute terrain allows detailed simulations of terrain-induced synoptic and mesoscale atmospheric flow patterns. The ten-minute terrain is interpolated to the RWM's 25, 50, or 100NM grid as appropriate.

e) RWM and GSM terrain are blended over the outer five rows/columns of the RWM domain. This terrain blending allows a smoother interpolation of GSM boundary fields into the RWM boundary region.

f) The RWM solves the primitive meteorological equations using a quasi-Lagrangian method. This method is special because it accounts for changes in acceleration of dependent variables, as well as changes in advecting velocity over the trajectory traced by the parcel in a time step. This quasi-Lagrangian method enhances the forecast simulation of jet streams, baroclinic zones, and developing disturbances through the preservation of strong gradients within the model.

g) RWM boundaries are updated with GSM forecast fields after each three-hour RWM forecast simulation period. RWM fields are nudged by these GSM forecasts through a relaxation scheme which is applied to the outer five rows/columns of the RWM domain.

h) The RWM runs on an expanded grid. This grid extends five points beyond the displayable boundaries of the model. Benefits of an expanded grid include removing the artificially forced RWM/GSM blending zone from the usable forecast region. Expanding the grid also further removes the coarser GSM's influence from the interior of the RWM forecast domain.

i) RWM fields are available at three-hour forecast intervals for standard pressure levels and at one-hour intervals (fixed windows only) for seven levels within the planetary boundary layer.

Weaknesses:

a) The RWM does not contain advanced physics; only basic physical processes are represented. These basic processes include: air-sea exchange of sensible and latent heat, surface friction, large and Kuo-type convective releases of latent heat, and dry convective adjustment. The RWM contains no solar or terrestrial radiation; therefore, no diurnal cycle is simulated in the forecasts. In addition, complex boundary layer processes such as fluxes of momentum, heat, and moisture are not included in the model's forecast solution.

b) Presently, the RWM does not contain its own analysis. Instead, the RWM must rely on an interpolated analysis or zero-hour forecast from the GSM.

c) The RWM only covers a limited geographical domain. This domain is confined to a 61 x 61 matrix of quarter-mesh grid boxes (expanded (71 x 71)) for the USA fixed window and contingency window, a 75 x 65 (expanded (85 x 75)) grid matrix for the European fixed window, and a 73 x 69 (expanded 83 x 79)) grid matrix for the Asian window. These restricted domains are the result of memory limitations on the Cray X-MP at AFGWC. The area1 coverage of each window is dependent upon which grid spacing is used; a window configured with 25NM grid spacing will cover a much smaller region than the same window configured to a 50 or 100NM grid spacing. In addition, the limited zonal and meridional window dimensions dictate significant GSM influence within the RWM forecast domain for 25NM grid spacing configurations.

See references k, 1, m.

A. Organization responsible: SYSM
B. Equipment: Unisys 1100/72 (Systems A), Cray
C. Input: HIRAS Analysis (temperature, winds, moisture, pressure)
GSM Database (boundary layer data, winds, pressure, temperatures, and moisture)
Sea Surface temperatures from FNOC

Output: RWM Database
- Used by the Battlefield Weather Observing

Forecasting System (BWOFS)
- Used by SDHS Boundary Layer Database
- Used by the Point Display Model.
- Used by the Selective Display Model

2.3.2.5 Global Spectral Model (GSM)

The GSM was developed by the NMC in 1980. AFGWC received GSM in 1984. It is used in two different capacities. First, the GSM is used as a first-guess model for HIRAS. Secondly, the GSM is used as AFGWC's primary non-cloud forecast model for aviation customers. Although the same source code is used for these two functions, there are slight differences.

The first-guess model is an R30-wave, 12-vertical layer resolution of the *GSM.* The vertical layers are concentrated near 25'0 mb. Since GSM is a spectral model, it's horizontal resolution is expressed in terms of waves. This works out to be about 350km east-west (at 35° north) and 270km north-south on the GSM internal grid. This model produces zero, six, and 12-hour forecasts of heights, winds, temperature, and moisture from the surface to 100 mb (moisture to 300 mb). The six-hour forecast is routinely used as the first-guess input for HIRAS. HIRAS also has the capability to use the 12-hour forecast if desired. Data are stored as spectral coefficients in a 2.5° x 2.5° latitude/longitude format and then interpolated to the AFGWC coarse mesh grid system. Fixed input fields are terrain, monthly sea surface temperature climatology, and surface roughness.

The primary forecast model is au R40-wave, 12-layer resolution of the GSM. This version produces forecasts of heights, temperatures, winds, and vertical velocity from the surface to 100 mb. *Forecasts are* available from zero to 96 hours, with three-hour intervals available to 48 hours. Data are stored in the 2.5° x 2.5° latitude/longitude format and then interpolated to the AFGWC coarse mesh grid system. HRCP uses the winds file produced by GSM. See Figure 13.

The following atmospheric processes are parameterized:

a) Topography - uses an R24-wave field.

b) Surface friction - varies with terrain.

c) Sensible heat exchange - transport from surface to

Global Spectral Model
(GSM)

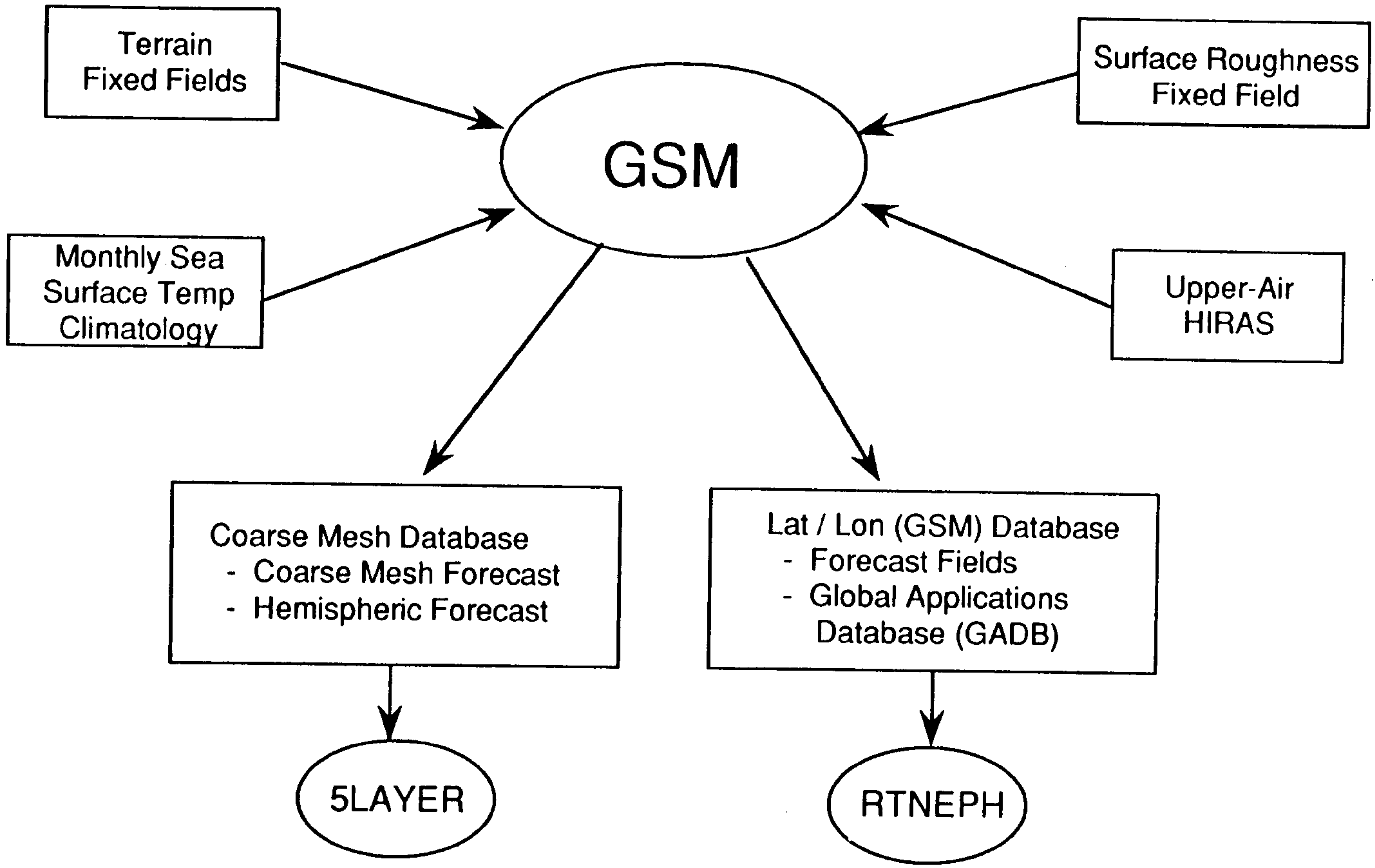


FIGURE 13

atmosphere modeled over the ocean only. No heat exchanged over land. Uses sea surface temperature climatology. *

d) Surface moisture flux - transport from surface to atmosphere modeled over oceans only. Produces a dry bias over land near the surface in the forecast. *

e) Precipitation - Uses Kuo scheme for convective precipitation. Large scale precipitation is also modeled. GSM is not a superior precipitation forecast model.

f) Radiation - No radiation parameterization. *

* These GSM problems contribute to a warm bias in the troposphere and a cold bias near *100* mb. They also cause GSM to be a bit too dry.

The GSM sets up on System A (Unisys 1100/72) and then executes the compute intensive portion on the Cray. It runs *four* times a day after HIRAS (once per six-hour cycle). GSM begins about 3.5 hours after cycle time. The 24-hour forecast is generally available about four hours after cycle time. After processing on the Cray, some post-processing is done *on* System A. The entire HIRAS/GSM cycle takes approximately six hours. GSM is written in *FORTRAN.*

Model Strengths and Weaknesses

Strengths

- Highly dependable; no recurring bugs in AWAPS hardware or software.

- Runs within operational time limits. Output databases are available in time for the many applications that use it.

- Long waves are handled well considering that the model was designed for flight-level forecasting.

Weaknesses

- Low resolution. The AFGWC GSM is an R40/12 model, compared to the T125/18 National Weather Service GSM and the T80/18 GSM of the Navy.

Lacks a stratosphere. The GSM cannot produce a stratospheric forecast.

- Lacks accuracy. Verification lags behind GSMs of other centers. Scientific improvements have not kept pace with improvements made at other centers. Poor performance is due to:

a. Low resolution
b. Lack of physics parameterizations
c. Sea surface temperatures are climatology
d. Lack of moisture at all layers

- Improvements are limited by hardware constraints

- Forecast wind speeds are typically too slow below the 100mb level.

- The GSM is generally too warm in the troposphere.

Since the GSM forecasts geopotential heights balanced with temperature, the geopotential heights are generally too high.

See reference n.

A. Organization responsible: SYSM
B. Equipment: Unisys 1100/72 (Systems A), Cray
C. Input: Upper-Air HIRAS
Terrain fixed field
Monthly sea surface temperature climatology
Surface roughness fixed field

Output: Coarse Mesh database
- Coarse Mesh Forecast
- Hemispheric Forecast
Latitude/Longitude (GSM) Database
- Forecast Fields
- Global Applications Database (GADB)

APPENDIX A

GRIDS

Appendix A: Grids

This appendix describes the grid types in use at AFGWC. See Reference n.

The starting point for any grid point-based model is the grid. The atmosphere is relatively shallow in the vertical, but broad horizontally. This is why the number of grid points in the horizontal is usually greater than the number of grid points in the vertical. In the horizontal, the grid points are equally spaced. In the vertical, points are "stacked" to represent those areas of the atmosphere that are commonly analyzed or that are of significance to the model (e.g., 850mb, 700mb, 500mb). Grid spacings and vertical stacking are chosen in such a way as to simplify the calculations of the forecast model and to provide outputs tailored for a specific customer's use.

A grid is a group of regularly spaced points that represent the intersection of regularly spaced and perpendicular lines. The standard and lowest resolution grid used at AFGWC is the whole mesh. Higher-resolution grids (or finer-mesh grids) use whole-mesh grid points as a starting point and have more grid points in the horizontal. For example, the half-mesh grid is simply a grid that contains the whole mesh grid points and one gridpoint between every whole mesh gridpoint.

Atmospheric motions on a scale smaller than the grid in use cannot be represented correctly because wavelengths must be equal to or greater than twice the distance between two adjacent grid points. Also, a wave is generally handled poorly if its wavelength is less than four grid points wide. Since many atmospheric events deal with motions smaller than 1,600 km (the distance covered by four successive whole-mesh grid points) grids with finer resolution were developed. These include the half-mesh, quarter-mesh, and sixty-fourth-mesh grids. As their names imply, the distance between grid points on the finer meshes is defined relative to the whole-mesh.

Whole-mesh grid points are exactly 381 km apart at 60 deg N relative to the earth's surface. This means that, because of the earth's curvature, resolution decreases toward the poles and increases toward the equator. At half-mesh, the grid points are 190.5 km apart. Higher resolution grids have successively smaller distances between grid points.

Stationary window grids use windows, or subsets of the whole-mesh grid, to cover specific areas of the globe such as the North American, European, and Asian continents.

The Satellite Global Database (SGDB) grid is a 64th-mesh grid which contains 16,777,216 points in the Northern Hemisphere. It is used in the SGDB display on the SDHS, with a resolution of about 5 km.

There are three grid types in use at AFGWC: polar stereographic, Mercator, and latitude-longitude.

Polar-stereographic *(PST)* Grids: The Northern (or Southern) Hemispheric Whole-mesh Reference Grid (sometimes called the "Northern Hemispheric Whole-Mesh Super Grid") is a 65x65 point whole-mesh grid based on the PST map. The domain for all PST grids are centered on the hemisphere (Northern or Southern) and include the entire hemisphere. The borders of the grids partially extend into the opposite hemisphere, but data in these overlap areas are usually ignored. PST grids are available in the half-, quarter-, eighth, and 64th-mesh resolutions. They are used extensively at AFGWC for various weather support functions.

Mercator Grids: These grids cover an area from 50 deg N to 50 deg S for tropical meteorological needs. They are based on the mercator map projection.

o The conventional Tropical Grid is used for conventional meteorological elements such as temperature, height, and wind.

o The Satellite Global Database Tropical Grid is used for processing satellite imagery.

Latitude-Longitude Grids: The Global Applications Database (GADB) grid and the High Resolution Analysis System (HIRAS) grid are the latitude-longitude grids in use at AFGWC. Both contain 10,585 points.

The RTNEPH horizontal grid is overlayed on a polar stereographic projection true at 60° latitude. There are two grids, one for each hemisphere. Each grid is a subset of the AFGWC Whole-mesh Reference Grid, but has a resolution of approximately 25NM rather than 200NM, and is therefore called an eighth-mesh grid. Each grid is a 512 x 512 matrix of points, with the poles located at grid point (257,257). Each grid has a total of 262,144 points, although only about 200,000 are on the hemisphere. Only a small number of points in the eighth-mesh grid need to be processed at any one time. Therefore, the grid is subdivided into a set of 64 RTNEPH boxes, arranged in an 8 x 8 matrix, and numbered 1 to 64. Each box contains a 64 x 64 set of eighth-mesh points. If a point is off the map projection (beyond the equator), it is not processed.

APPENDIX B
SECONDARY MODELS

Appendix B: Secondary Models

NAME OF FUNCTION: CUFCST

POC FOR DESCRIPTION DATA: SYS
PHONE: (402) 294-3986

1. GENERAL

   A) FUNCTION ABSTRACT: *Forecasts* cumulus cloud coverage in Europe and Western Asia. Produces a three, six, and nine hour forecast.

   B) REFERENCE DOCUMENTS: CUFCST Software Binder, CUFCST User's and Maintenance Manuals, CUFCST Software Development Folder.

   C) TERMS AND ABBREVIATIONS: HRCP, *XTSFC (Surface* regions database), XTPRB (Upper-air regions database), DOS (Special Operations Branch), RAOBs (Rawinsonde)

2. SYSTEM SUMMARY

   A) USE AND PURPOSE *OF* FUNCTION: Runs twice *a day* from 1 Apr: to *30* September to supplement the forecast cloud amounts . HRCP. Relieves DOS from a labor intensive manual cumulus.

   B) PURPOSE *OF* PROCESSING FUNCTIONS: To analyze upper-air soundings and surface observations and to calculate stability indices and temperature forecasts.

   C) EXTERNAL INTERFACES *FOR* FUNCTIONS: Upper-air and surface regions databases.

   D) INTERNAL INTERFACES *FOR* FUNCTIONS: Updates a file called HRCP*HRCPQFILE that is accessed by HRCP.

   E) OPERATIONAL SCENARIO: Program is run twice a day at approximately 03002 and 06002 from 1 April through 30 September for input into the HRCP.

   F) OPERATIONAL CONSTRAINTS, LIMITATIONS OR ASSUMPTIONS: CUFCST is designed to forecast fair weather cumulus, i.e., cumulus formation due to surface heating with vertical instability.

3) DETAILED CHARACTERISTICS:

A) MAJOR PERFORMANCE REQUIREMENTS: Cumulus cloud forecasts with a mean absolute error not greater than 2/8th coverage. Forecast surface temperatures with a mean absolute error not greater than 2.5° C.

B) DATA INPUT TO FUNCTION: XTSFC and XTPRB.

C) DATA OUTPUT FROM FUNCTION: HRCP*HRCPQFILE to the HRCP.

D) SOFTWARE SEQUENCE RELATIONSHIPS: None

E) SOFTWARE SIZING AND TIMING: 128K, 18 seconds CPU time, approximately 25 seconds wall time.

F) CAPACITY REQUIRED: See 3E

G) SOFTWARE ACCURACY AND VALIDITY REQUIREMENTS: Forecast cumulus cloud coverage within ± 2/8th. Forecast surface temperature within ± 2.5° C.

H) BACKUP/DEGRADED OPERATIONS PROCEDURES: None, unmodified HRCP.

4) ENVIRONMENT:

A) HARDWARE USED IN PROCESSING: Unisys 1100/91

B) AUTOMATIC PROCEDURES USED IN TASK: Fully automated, @START U*I.CUFCST or ST CUFCST.

C) MANUAL PROCEDURES USED IN TASK: Sign on to a System 3 scope and type @START U*I.CUFCST.

D) OPERATING SYSTEM: 3/R Unisys 1100/91

E) LANGUAGE: Fortran 77

5) SECURITY

A) SECURITY LEVEL FOR FUNCTION: Unclassified

NAME OF FUNCTION: MODCUF

POC FOR DESCRIPTION DATA: SYS
PHONE: (402) 294-3986

1. GENERAL

   A) FUNCTION ABSTRACT: Forecast6 cumulus cloud coverage in Europe and Western Asia. Produces a three, six, and nine hour forecast. (See CUFCST)

   B) REFERENCE DOCUMENTS: CUFCST Software Binder, CUFCST User's and Maintenance Manuals. CUFCST Software Development Folder.

   C) TERMS AND ABBREVIATIONS: XTSFC (Surface Regions Database), XTPRB (Upper-Air Regions Database), DOS (Special Projects Branch)

2. SYSTEM SUMMARY

   A) USE AND PURPOSE OF FUNCTION: Runs twice a day from 1 Apr to 30 September along with CUFCST. But instead of writing the forecast values to a file, MODCUF places them into arrays and then prints them out onto six 64 x 64 BOXIJ maps for the DOS forecasters.

   B) PURPOSE OF PROCESSING FUNCTIONS: To analyze upper-air soundings and surface observations to calculate stability indices and temperature forecasts.

   C) EXTERNAL INTERFACES FOR FUNCTIONS: XTSFC and XTPRB

   D) INTERNAL INTERFACES FOR FUNCTIONS: Arrays ICUFCT (64,64,6) and MODCUF (128,192).

   E) OPERATION?& SCENARIO: Program is run twice a day at approximately 03002 and 06002 from 1 April through 30 September for input into the HRCP.

   F) OPERATIONAL CONSTRAINTS, LIMITATIONS OR ASSUMPTIONS: Designed to forecast fair weather cumulus, i.e., cumulus formation due to surface heating with vertical instability.

3) DETAILED CHARACTERISTICS:

A) MAJOR PERFORMANCE REQUIREMENTS: Cumulus cloud forecasts with a mean absolute error not greater than 2/8th coverage. Forecast surface temperatures with a mean absolute error not greater than 2.5° C.

B) DATA INPUT TO FUNCTION: XTSFC and XTPRB

C) DATA OUTPUT FROM FUNCTION: MODCUF array to printer (hardcopy output).

D) SOFTWARE SEQUENCE RELATIONSHIPS: None, but for accuracy and comparison with CUFCST it should be run as close to CUFCST as possible.

E) SOFTWARE SIZING AND TIMING: 126K, 18 seconds CPU time.

F) CAPACITY REQUIRED: See 3E.

G) SOFTWARE ACCURACY AND VALIDITY REQUIREMENTS: Forecast cumulus cloud coverage within ± 2/8th. Forecast surface temperatures within ± 2.5° C.

H) BACKUP/DEGRADED OPERATIONS PROCEDURES: None

4) ENVIRONMENT:

A) HARDWARE USED IN PROCESSING: Unisys 1100/91

B) AUTOMATIC PROCEDURES USED IN TASK:' Fully automated.

C) MANUAL PROCEDURES USED IN TASK: Sign on to a System 3 scope and type @START U*I.MODCUF.

D) OPERATING SYSTEM: 3/R Unisys 1100/91

E) LANGUAGE: Fortran 77

5) SECURITY

A) SECURITY LEVEL FOR FUNCTION: Unclassified.